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International Responses to Japanese Plutonium Programs

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Abstract

Japanese plutonium programs have aroused considerable concern from a variety of sources abroad. These concerns have been raised by disparate individuals, nations and organizations and have persisted notwithstanding Japanese attention to safety and careful adherence to formal international requirements. This study explores these concerns and makes suggestions that could reduce them and benefit the international nuclear non-proliferation regime.

International apprehension over Japanese plutonium programs is fueled by their implications for nuclear proliferation, by the unconvincing nature of the official rationales behind the programs, and by lack of appreciation of background factors that are major drivers behind the programs. Stripped of caveats and qualifications, our explanation for these international concerns reduces to the following essentials.

First, proceeding with commercial-scale plutonium programs increases the likelihood that other countries will follow the Japanese example, perhaps with less physical security against theft by subnational groups or diversion for weapons use. Long-term R&D intended to maintain technology options as insurance against unfavorable energy developments, on the other hand, would not raise similar concerns.

Second, the extensive Japanese commitment to plutonium programs appears to be incommensurate with the benefits advanced in the official rationales for these programs. In an international climate in which safety and proliferation dangers of nuclear energy are considered by many to be of paramount importance, the official rationales of energy security, economic benefits, and environmental advantages are not convincing to many foreign observers.

Third, a set of background factors provides a relatively benign explanation of these programs. These factors include local politics, the inertia of large organizations, industrial interests, and cultural factors. Insufficient appreciation of these background factors contributes to criticism of Japanese plutonium programs, especially in the light of proliferation risks and skepticism about the official rationales for the programs.

This study traces the implications of international responses to the Japanese programs and suggests ways to mitigate international concerns. Our primary recommendations involve modifications of existing programs rather than simple repackaging of existing initiatives. These modifications include diversifying aspects of the fuel cycle program, emphasizing long-term R&D, avoiding premature commercialization of plutonium, opening further the policy process, enhancing confidence-building measures, providing vigorous support for non-proliferation measures, and not encouraging commercial plutonium programs in other countries.

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I. OVERVIEW OF PLUTONIUM PROGRAMS

Japan has long been committed to "closing the fuel cycle" by reprocessing spent fuel from light water reactors (LWRs) to recover plutonium that would then be recycled in mixed oxide fuel (MOX) in LWRs and eventually in fast breeder reactors (FBRs). The overall objective is to derive maximum energy from uranium resources. It was thought that closing the fuel cycle would contribute to energy security, reduce energy costs, and ease waste management difficulties. In the early stages, however, demand in Japan for reprocessing of spent fuel was driven by the need to manage accumulating spent fuel, for which there were limited storage facilities at reactor sites. The lack of domestic capacity for reprocessing led Japan to contract with the U.K. and France for reprocessing services; hence the need to transport spent fuel, recovered plutonium, and vitrified high level waste between Europe and Japan.

Recent policy developments have slowed implementation of the overall program. The latest long-term program of the Japanese Atomic Energy Commission (JAEC), published in 1994, introduced an explicit "no plutonium

surplus" policy, postponed the second commercial reprocessing plant, the advanced thermal reactor (ATR) and the FBR commercialization schedule, and mandated increased "transparency" of the program. In July of 1995, the Federation of Electric Power Companies asked the JAEC to cancel the Demonstration Advanced Thermal Reactor (DATR) as a cost reduction measure. Japan Nuclear Fuel Limited (JNFL), the commercial reprocessing company, also announced a further one year delay in the schedule for construction of the Rokkasho reprocessing facility. These changes have, in effect, scaled down the plutonium programs, stretched out construction plans, and opened the program to greater outside scrutiny. However, the underlying commitment to recycling and breeder reactors remains.

II. INTERNATIONAL PERCEPTIONS OF DIRECT AND INDIRECT PROLIFERATION RISKS

Japan rightly stresses that it gives intensive attention to the physical security of its nuclear programs and to minimizing risks of weapons proliferation. However, Japanese plutonium programs raise significant concerns outside Japan. Some critics are motivated by profound opposition to any form of nuclear power, a view that would be satisfied only by a policy that would close the entire nuclear power program. Other concerns, however, have been raised by observers and analysts who are not opposed in principle to nuclear power. These latter concerns have attracted the attention of nuclear program planners in the public and private sectors in Japan who recognize that the international political environment may become less tolerant of programs that appear to threaten safety or to increase the danger of nuclear weapons proliferation. These concerns may be summarized as follows.

(i) Demonstration Effect: The most important issue is the possibility that the very existence of Japan's program, especially at a commercial scale requiring a significant commitment of scarce resources, will be cited as a precedent or justification, genuine or insincere, for other nations to follow suit with their own reprocessing and breeder programs. Other nations may not give the equivalent attention to safety and proliferation considerations that Japan has shown, or have the capability to do so. In fact, Japan's program is currently being cited as a precedent by others, especially in East Asia.

(ii) Plutonium Stockpiles: Japanese pledges to avoid creating an uncommitted plutonium surplus by balancing supply and demand and to increase the transparency of its records on plutonium stocks are important. But international concern has persisted nonetheless for several reasons. First, MOX fuel demand for LWRs is artificial, in the sense that the amount of plutonium to be consumed by LWRs may be adjusted up or down at will. Second, while Japan may be able to eliminate plutonium stockpiles over the long term by matching demand to the total plutonium to be obtained by reprocessing, substantial stockpiles may occur along the way if MOX or breeder programs are delayed. For example, according to Japanese government figures, Japan's current total plutonium stockpiles are about 10.8 tons (4.6 tons in Japan and 6.2 tons in Europe). Third, in the steady state, substantial amounts of plutonium may be necessary as "running" stock, providing in effect a stockpile until actual use.

Each of these points could serve as a justification by other countries in the region to move toward overt or clandestine nuclear weapons development programs, citing the real or feigned fear that Japan's plutonium "stocks" could become the basis of a Japanese weapons program that would be a threat to them. Japanese plutonium would be reactor-grade only, but the distinction between reactor and weapons grade plutonium is not sufficiently meaningful in this context. As the 1994 report of the National Academy of Sciences (NAS), "Management and Disposition of Excess Weapons Plutonium," and other studies have indicated, reactor grade plutonium can be used to build both crude and sophisticated nuclear weapons. Although the potential risks associated with Japanese plutonium stockpiles are less serious than those not fully accounted for, as in Russia, Japanese running stocks and the ability to accumulate more are a cause of significant concern, especially in the East Asian region.

(iii) Protection Against Diversion: Japan has been meticulous in observing international safeguards and physical protection standards. But the effectiveness of those systems in the context of large-scale plutonium use has not been demonstrated. Japan argues that the existence of the Rokkasho plant will allow further development and testing of safeguards for plutonium. However, increases in plutonium stocks, in international transfers of fissile materials, and in the complexity of the system will greatly increase the difficulties of system management. This

could jeopardize the adequacy of the international safeguard system and of physical protection against sub-national diversion. Timing is important. Until there are fully reliable means of safeguarding large-scale plutonium use, such programs will raise significant international concern.

(iv) Weapons Options: Although there have been expressions of concern outside Japan about Japanese weapons intentions, there is no evidence that the Japanese plutonium programs were developed to enhance the ability of Japan to build nuclear weapons. In fact, the existence of a large-scale reprocessing plant has only limited effect on the country's nuclear weapons options. Japan now has the fissile material and technical expertise to produce a significant number of nuclear weapons in a brief time if it were to choose to violate international safeguards. The presence or absence of a commercial plutonium facility does not change that situation, though it would permit a larger diversion of fissionable material for any given threshold of confidence, standard of observation, or level of monitoring technology. However, the perceived relationship of the reprocessing program to a weapons option has contributed to foreign apprehension about Japanese intentions with respect to nuclear weapons. That concern, which is at a low level today, would be likely to grow over the years as plutonium operations grow.

(v) Plutonium Shipments: The physical protection of shipments of plutonium and vitrified waste from Europe back to Japan was the source of much of the recent public criticism of the Japanese plutonium programs. The physical risks cannot be completely eliminated, but Japan's attention to the dangers appear to have minimized them. The publicity was due in part to the actions of nuclear power opponents, but the lack of a convincing set of rationales for the overall program as discussed below contributed to the adverse attention. Minimizing the number of shipments and providing adequate information about them would help to reduce reaction to future shipments. However, in the context of the questions about the reprocessing program itself, some criticism is bound to continue. Obviously, attention to shipments will decline if and when they are no longer necessary as a result of expansion of reprocessing capability within Japan. However, reduced criticism on this score would be more than offset by increased international concern over the implications of domestic commercial plutonium programs.

III. INTERNATIONAL PERCEPTIONS OF PROGRAM RATIONALES

The various arguments presented by Japan in defense of its plutonium programs are not seen as sufficiently convincing by parties in other countries to explain the extent and expense of the commitments to them. These official rationales include arguments that the plutonium programs improve energy security, provide economic benefits, and offer environmental advantages.

A. Energy Security

The most common argument presented by Japan for closing the fuel cycle is that uranium resources on a global basis will eventually be limited, so that the energy content in uranium should be used to the maximum extent possible. According to this argument, commitments to nuclear power in other countries are likely to increase and create competition for scarce supplies. Japan does not have significant indigenous energy resources, either of fossil fuel or uranium, so that the buildup of a reliable indigenous source is seen to be essential to improve the nation's energy security against the danger of supply interruption. Moreover, it is argued that a commercial scale Japanese program would actually assist others by reducing global demand for uranium.

Most resource economists and geologists who work on uranium would challenge the premises of this argument. First, the economics of natural resources, and past history of resource availability, suggest that uranium reserves would be found to be larger if demand were to increase and prices rise. Second, there are other, less expensive and less controversial, paths to extending and securing uranium resources. These include investing more in developing new uranium supplies in many promising regions, diversifying supply sources, stockpiling to buffer against supply interruption, and improving fuel efficiency through higher burn-up LWRs. Finally, an overwhelming commitment to plutonium and breeder reactors in commercial programs could, paradoxically, make Japan's energy system increasingly vulnerable to major accidents, proliferation or terrorist incidents, or policy changes elsewhere over which Japan has no control.

Reassuring predictions about the availability of resources in the face of possible resource shocks in the future may not be fully satisfying for a nation with limited indigenous resources. This is especially so for Japan for whom energy security concerns have a long history and a symbolic significance that may not be as strong in other nations. One of the underlying rationales for the plutonium program has therefore been to maintain a technology option in case uranium resources are not as plentiful as forecast, or in the event of the need to move more energetically to nuclear power if there are increased environmental threats from the consumption of fossil fuels.

However, a commitment at this time to a commercial program is not needed to achieve that technological objective. Moreover, importing French technology instead of developing indigenous technology for the Rokkasho plant is not likely to maximize technological development on either a global or national basis. Long-term R&D on an advanced reactor and nuclear fuel cycle, as well as on other alternatives to fossil fuels are at least as appropriate, and would avoid a premature massive commitment to today's technology that may become obsolete as new technological options develop. Operating experience could be gained through a commercial program at this time, but at great cost and with only modest technological gain. The present focus on reprocessing and plutonium recycling, with relatively minor investments in alternative ways of extending uranium resources, contributes to international skepticism over the energy security rationale for the program.

B. Economic Benefits

A second important rationale commonly offered centers on the long term economic viability of nuclear power with reprocessing. Japanese analysts would now acknowledge that plutonium recycling is likely to be more expensive than the once-through option, but the estimated additional cost is seen as marginal given the small share of fuel cost in the final cost of electricity. In addition, they argue that plutonium recycling and use of breeders can bring long term price stability in nuclear-generated electricity. Thus, the programs are justified as a long-term investment in cost stabilization.

International acceptance of this argument has been limited. Criticism centers on cost differences between the once through nuclear fuel cycle and recycling. For example, even under conservative assumptions, cost estimates of the recycling option may be significantly higher than the costs of the once-through option. The 1994 study of the Nuclear Energy Agency (NEA) of the OECD estimated the long term costs of direct encapsulation and disposal of spent fuel at 140-640 ECU per kg, compared to the cost of reprocessing of spent fuel plus vitrification of high level waste at 630-1300 ECU per kg. However, these differences are diluted when considered as a portion of total power generation costs.

Even in Japan, where nuclear power is often estimated to be the least-costly power source, the cost penalty of the commercial reprocessing/recycling program could be large enough to raise the cost of nuclear generated electricity above that of electricity generated by fossil fuels. With deregulation, utilities are under increasing pressure to reduce costs. In fact, pressures to avoid increasing nuclear power generating costs may have spurred the Federation of Electric Power Companies' July 1995 request for cancellation of the DATR project.

C. Environmental Benefits

A third rationale is that the reprocessing of spent fuel will reduce the burden of radioactive waste management. This argument is based on the expectation that the volume of vitrified high-level waste from reprocessing will be significantly smaller than the volume of the spent fuel itself. In addition, the removal of plutonium from waste decreases short term hazards of ingestion and inhalation and reduces the toxicity of the waste in the long-term. These potential benefits, it is argued, can ease the difficulty of managing nuclear waste and thus improve the political acceptability of nuclear power itself. A natural extension of this reasoning is that it would be even more advantageous to separate or partition not only plutonium but also all minor actinides from spent fuel. Then these long-lived radioisotopes could be recycled as fresh fuel in a reactor where they would either be fissioned or transmuted to stable species. The high-level waste for geologic disposal would then consist exclusively of fission products. The potential benefits of such a fuel cycle for waste management have led to R&D programs on actinide partitioning and recycling in France, Japan and Russia. A similar American program was recently terminated.

Criticism of both standard reprocessing with plutonium recycling, and partitioning and recycling of all actinides has centered on several points. First, space requirements for geologic disposal of spent fuel or high-level waste are initially driven by heat generation rather than volume. For roughly the first hundred years after reactor discharge, heat generation is essentially a function of fission product, rather than actinide concentration. Thus, unless spent fuel is stored for more than a hundred years before final deposition, reprocessing produces no advantage compared with direct disposal of spent fuel in this respect. Second, the reprocessing/partitioning operation itself creates additional streams of transuranic low and intermediate level wastes which also require disposal. Third, it is unclear whether standard reprocessing or even actinide partitioning will significantly reduce the long-term hazard of buried waste. This hazard is a function both of the toxicity of the contained radionuclides in situ and the pathway from the waste to the environment. Further, any reduction in the hazard of buried waste due to standard reprocessing or actinide reprocessing/partitioning and recycling must be balanced against the increase in the operational risks to both employees and the public. Finally, R&D on actinide partitioning and recycling is still in an early stage, and it is unclear whether the required technology can be developed, and at what cost.

At this time, the claimed environmental benefits of all alternatives are uncertain. A compelling case cannot be made in favor of standard reprocessing with separation of plutonium, advanced reprocessing with complete partitioning of all the actinides, or direct disposal of spent fuel.

IV. UNDERRECOGNIZED BACKGROUND FACTORS

Circumstances have changed since the basic contours of Japanese reprocessing and breeder plans were first formulated more than 30 years ago. All the claimed advantages -- security, political, and economic -- that appeared initially to favor plutonium use have changed. Yet the rationales and main elements of the Japanese plutonium program have not changed. International apprehensions have been fueled by this mismatch between a changing context and a relatively static program.

This study argues that background factors that are common to Japan and most other countries may provide benign, though unflattering, explanations for the continuity of Japanese plutonium programs. These factors include local politics, the inertia of large organizations, industrial interests, and cultural factors. As skepticism about official rationales fuels apprehension over proliferation risks, international failure to recognize these background factors contributes to criticism of Japanese programs.

While the scope of our study did not make it possible to investigate these factors in detail, we observed much evidence of their existence. They are typically not presented in policy documents, yet they may be of great importance in influencing decisions, especially for mature programs with long-standing multinational commitments and monetary investments. If such factors were more visible outside Japan as a result of a more transparent policy process, or were acknowledged in some way, international criticism might be significantly muted.

A. Law and Local Politics

As a result of legislation, government programs, and community attitudes, the reprocessing of spent fuel as a means of managing nuclear waste became in effect a prerequisite for the siting of nuclear power plants in Japan. The nuclear plant siting law required utilities to specify in advance their disposal methods for spent fuel, while local communities in turn have insisted on early removal of spent fuel as a condition for accepting nuclear plants. Since the JAEC long-term plan specified that reprocessing/recycling is an "essential" aspect of Japan's nuclear programs, in part as a necessary step in waste disposal, the utilities had relied on the availability of reprocessing as the only legal basis for operating nuclear power plants.

Rokkasho Village is a central site for the Mutsu-Ogawara project, one of the largest regional development projects coordinated by the government and private industry. The overall project proved to be smaller than originally expected in the 1970s, so that the nuclear fuel cycle portion became more economically important for the local community. Though there has been some community opposition to the nuclear project, the economic benefits to the village and to Aomori prefecture are already substantial, and the project has been accepted on

this basis. Any change in the scope of the project, especially one that would leave the waste disposal site but delete the reprocessing plant without substituting other significant activities, could stimulate local opposition. The combination of the utilities' statutory need for formal nuclear waste disposal options, the economic benefits to the community, and the local political unacceptability of waste disposal without other activities is not fully appreciated abroad. Yet it is because of these factors that reprocessing has become embedded in the overall nuclear program, quite independent of cost and benefit calculations.

B. Organizational Inertia and Decisionmaking Processes

Large organizations have a natural inertia that makes significant policy change, especially reversal of policy, difficult to accomplish. In this case, fast breeder reactors and reprocessing are considered national projects, for which government agencies and private industry have made major institutional commitments over many years. The commitment to plutonium is not confined to Japan. The vision of low-cost abundant energy has been held by many other countries as well (France, Russia, India) and is not easily abandoned, especially when large international commitments have been made. In addition, the formulation of the JAEC's long-term program has involved three key government agencies, two national research institutes, the nuclear suppliers industry, and most of the utilities. Even if there is understanding that conditions have changed and programs ought to be altered, that can only be done gradually. Moreover, officials believe consistency of governmental commitment is important for both planning purposes and for the maintenance of orderly governmental processes so as not to put into question the validity of past or future commitments. The result of these factors can be seen in the gradual stretching out of the planned recycling programs while maintaining the formal long-term commitment.

Foreign observers have generally not recognized that there have been incremental changes to the program, repeated slippage of large project schedules, and cancellation of small projects. The natural conservatism of the policy process and the likelihood of international misunderstanding are both enhanced when the process is closed. That has been the case with Japanese nuclear policy in the past, as a result limiting debate among all interested parties, and discouraging open comparison among alternative policy choices. Recent efforts of the Japanese government and industry to increase the transparency of nuclear power plans and options and to provide greater openness of the policy process may well reduce international apprehension.

C. Industrial Interests

The fuel cycle business is increasingly important for the Japanese nuclear supplier industry, both because of its size and because of declining expectations for future reactor orders. The Rokkasho project, which includes an enrichment facility, a low-level waste depository, a reprocessing plant, and a high-level waste storage facility, is already one of the largest in Japan. Asahi Shimbun reports capital costs of the reprocessing plant alone in excess of $20 billion, even larger than the Kansai International Airport. The participants in the Rokkasho project include almost all major industrial groups in Japan, as well as the French nuclear supplier industry. The industrial stakes in Rokkasho are substantial indeed, and are an important factor in determining policy.

In addition to directly serving industrial interests, the Rokkasho project at its planned size is seen by some to serve a general Japanese interest in maintaining a strategic nuclear industrial base to meet possible future need or markets. American legislators, for example, have similarly defended continuing production of some large weapons systems using the same argument, notwithstanding the mitigation of the Soviet/Russian threat. The American case has centered on the need to preserve the existing nuclear industrial base against unanticipated future contingencies. The case for retention of the Rokkasho facility, despite the changes in context, has much in common, but the parallel is not well understood abroad.

D. Cultural and Technical Values

All nations are affected in their planning by traditions, historical experience, and cultural attitudes. Japan is no exception. Many elements stemming from those roots enter into plans to develop nuclear power, such as the importance of energy security discussed earlier. Another conditioning element is a cultural view that it is wrong, or worse, to waste resources. Accordingly, there is a strong appeal to the argument that the maximum value should be realized from all resources, in this case uranium. Hence, closing the fuel cycle as a way of extracting

all of the usable energy from the uranium atom has been a significant goal in nuclear power planning.

Arguments for reprocessing and breeder programs as the means to extract the last joule from every milligram of uranium are not only a result of the national culture. The world's nuclear engineering communities at one time all shared this view, for the commitment to best engineering practice by maximizing physical efficiency and minimizing waste is a matter of deep conviction for many engineers. This intense and genuine background factor clearly plays a significant role within the Japanese nuclear policy community but is little recognized outside the country.

V. FUTURE INTERNATIONAL IMPLICATIONS

Continuation along the current policy path will be likely to have several international implications for Japan:

1. The commitment to plutonium programs, in particular to the development of commercial-scale reprocessing, will likely engender continuing international attention and concern;

2. The credibility of the overall nuclear program may be put at risk since the rationale of the entire program is closely linked to the successful commercialization of plutonium;

3. Serious events or policy changes outside Japan over which Japan will have no influence, such as a proliferation or terrorism event or a serious incident involving plutonium could have a major impact on the Japanese program; and

4. International concern about proliferation could become focused on Japan, as a by-product of dealing in other contexts with weapons-grade plutonium issues, and as other nations use Japan's program as a rationale for their own plans to extract and store plutonium or to mount weapons development programs.

VI. SUGGESTIONS FOR MITIGATING INTERNATIONAL CONCERNS

In the light of this analysis, the authors offer suggestions that may be useful in the next nuclear power planning cycle in Japan.

1. Diversifying aspects of the fuel cycle program

The rationales offered for the plutonium programs, particularly those concerned with energy security and waste management, would have greater credibility if other possibilities than recycling that could serve the same goals were being more actively pursued (e.g. increasing support for uranium ventures, purchasing shares of new uranium mines, developing facilities for indigenous spent fuel storage and investing heavily in the development of alternative energy technologies). Even countries with advanced reprocessing programs such as France, Germany and the U.K. have conducted comprehensive reviews of alternative waste management options. This assessment of alternatives is an important piece that is missing in Japanese programs. The review would likely improve public confidence in the selection of technologies and policy options. It should be noted that reprocessing and the once-through option can be pursued in parallel, which can increase the flexibility of the entire nuclear power program.

2. Emphasizing long-term R&D

We recommend emphasizing a long-term R&D program with the goal of producing more innovative technologies in the fields of waste management, enhanced safety and improved economics. Some research on reprocessing and breeders is also justified as a way of preserving a technological option if ever needed in the future. Such an R&D program would arouse relatively little international concern.

3. Avoiding premature commercialization of plutonium use

The authors believe that other countries would be less concerned if the commercial plutonium programs were stretched out, scaled down or suspended. Significant alteration along those lines in the Rokkasho reprocessing project would result in slower and smaller MOX recycling programs in LWRs. This would also shift Japanese reprocessing policy from a supply driven basis, where demand is created in order to consume plutonium supplied by reprocessing, to a demand driven basis, where reprocessing takes place only when a need exists. Such changes would also reduce the costs borne by Japanese utilities. Substitution of other activities would be necessary to mitigate local reaction to a reduction in plans for Rokkasho.

4. Further opening of the policy process

Notwithstanding the positive changes that have made the policy process more transparent, greater availability of information and more opportunities for public debate about nuclear policies would serve both to improve public knowledge of policy alternatives and would reassure foreign critics who believe there has been inadequate discussion of the choices Japan has made. Expanding the practice of seeking independent analysis can over time make for a policy process whose conclusions are more readily accepted internationally.

5. Enhancing confidence-building measures

Prominent efforts, some already undertaken, to open Japanese programs to foreign participation, inspection, and internationalization would serve the useful goal of deflating any concerns about ultimate Japanese intentions in its nuclear programs. Rhetoric alone is not enough, especially in the light of the questioned motivations of the program. Involving scientists of other countries in cooperative nuclear R&D, moving seriously to explore possible international mechanisms for control of plutonium stocks, and other such programs can help to improve international confidence in the Japanese program. Japan is well-placed to work with other nations, especially in Asia which is likely to see the greatest expansion of nuclear power in coming decades, and to create a framework that will promote safe peaceful use and discourage proliferation.

6. Providing vigorous support for non-proliferation

The recent indefinite extension of the Nuclear Non-Proliferation Treaty (NPT), with the vigorous support of Japan and the United States, sets up the next stage of international non-proliferation policy. It is important that Japan be in the vanguard of support for implementation of the NPT and for non-proliferation in general, even if that means opposition to plutonium programs in other countries that could raise questions about Japan's own program. Willingness to be a model for plutonium monitoring and inspection, to provide financial support for the International Atomic Energy Agency (IAEA), and to participate in the efforts to reduce the risk of newly surplus weapons-grade plutonium are among the measures that can help to deflect criticism of the Japanese program. In fact, by accepting excess weapon plutonium for peaceful use, Japan could suspend or further delay its own reprocessing program. Plutonium shipments for such a purpose would likely face less international concern, and could conceivably attract support.

7. Not encouraging commercial plutonium programs in other countries

Whatever arguments Japan has for proceeding toward a "plutonium economy" within Japan, many responsible observers believe it would be very dangerous if the world at large accepted the widespread commercial use of plutonium in nuclear power programs. It is tempting for Japan to encourage reprocessing and breeder reactors in other countries as a way to dilute the criticism of Japan's program, and along the way develop a commercial market for Japanese technology. In our view, such actions would greatly increase foreign criticism of the Japanese program.

INTERNATIONAL RESPONSES TO JAPANESE PLUTONIUM PROGRAMS

MAIN REPORT

INTRODUCTION

Historically, Japan has had to rely almost exclusively on foreign sources of energy, and has been acutely aware over many years of that dependence. The 1973 oil crisis was perhaps the most visible of many recent events that dramatized for Japanese officials and the public at large the extent of vulnerability to outside events. The development of nuclear sources of energy, using technology that could be wholly based on Japanese soil, appeared as an exciting new possibility that could over time greatly reduce that energy dependence.

The particularly exciting aspect of nuclear power to Japan was that it appeared to be possible to create a completely indigenous source of energy through the use of the plutonium produced as a byproduct of the generation of power in light water reactors (LWRs). Plutonium can be separated from spent reactor fuel and then recycled to augment the original uranium fuel, or used in breeder reactors that would have the capacity to produce more plutonium than they consume. In time, Japan could in principle have a self-sufficient energy source able to provide a substantial portion of the country's electricity needs.

Japanese plutonium programs have, however, aroused considerable concern from a variety of sources abroad. Concerns have been raised by disparate individuals, nations and organizations and have persisted notwithstanding Japanese attention to safety and careful adherence to formal international requirements. Some concerns are motivated by profound opposition to any form of nuclear power, a view that would be satisfied only by a policy that would close the entire nuclear power program. Other concerns, however, have been raised by observers and analysts who are not opposed in principle to nuclear power. These latter have attracted the attention of nuclear program planners in the public and private sectors in Japan who recognize that the international political environment may become less tolerant of programs that appear to threaten safety or to increase the danger of nuclear weapons proliferation. This study explores these concerns, and makes suggestions that could reduce them and benefit the international non-proliferation regime.[1]

Sources of International Concern

International apprehension over Japanese plutonium programs is fueled by their implications for nuclear proliferation, by the unconvincing nature of the official rationales behind the programs, and by lack of appreciation of background factors that are major drivers of the program. Stripped of caveats and qualifications, our explanation for the international concerns reduces to the following essentials.

First, proceeding with commercial-scale plutonium progams increases the likelihood that other countries will follow the Japanese example, perhaps with less physical security against theft of plutonium by subnational groups or diversion for weapons use. Long-term R&D intended to maintain technology options as insurance against unfavorable energy developments, on the other hand, would not raise similar concerns. (Chapter II)

Second, the extensive Japanese commitment to plutonium programs appears to be incommensurate with the benefits advanced in official rationales for these programs. In an international climate in which safety and proliferation risks of nuclear energy are considered by many to be of paramount importance, the official rationales of energy security, economic benefits, and environmental advantages are not convincing to many foreign observers. (Chapter III)

Third, a set of background factors provides a relatively benign explanation of what drives these programs. These factors, found in one form or other in all countries, include local politics, the inertia of large organizations,

[1]In this report, the authors analyze the source of these concerns, without reference to the overall desirability of Japan's reliance on nuclear energy. The basic commitment of Japan to a large-scale light water reactor program for the generation of electricity is assumed, and not questioned, in this study.

limited transparency of the policy process, industrial interests, and cultural considerations. Insufficient appreciation of these factors outside Japan contributes to criticism of the plutonium programs. (Chapter IV)

Implications and Suggestions

This study traces the implications of the international responses to the Japanese programs and suggests ways to mitigate international concerns. Our primary recommendations involve modifications of existing programs rather than simple repackaging of existing initiatives. These modifications include diversifying aspects of the fuel cycle program, emphasizing long-term R&D, avoiding premature commercialization of plutonium use, opening further the policy process, enhancing confidence-building measures, providing vigorous support for non-proliferation measures, and not encouraging commercial plutonium programs in other countries.

These suggestions, we believe, would not only reduce international apprehension but also generate various benefits for Japan's nuclear programs and the global non-proliferation regime such as:
-More flexible and diversified nuclear programs
-Less costly but more innovative technological development
-Increased confidence in Japan's intention to use plutonium for peaceful purposes
-Mitigation of world-wide pressure on the management of surplus weapons-usable materials.

I. OVERVIEW OF JAPANESE PLUTONIUM PROGRAMS

Origin of the Program

The origin of Japan's plutonium programs can be found in the first "Long-Term Program for Development and Utilization of Atomic Energy" published in 1956 by the Japan Atomic Energy Commission (JAEC). The Commission itself was created under the Basic Atomic Energy Law enacted in 1955. In the 1956 report, the JAEC set the basic goal of Japan's nuclear reactor and fuel cycle development:

> ...it is our basic policy to conduct reprocessing using domestic technology as much as possible and [this] will be exclusively done by [the] Japan Atomic Fuel Public Corporation... Mainly [for] effective utilization of nuclear fuel resources, [the] breeder reactor is the most appropriate type of reactor for Japan, thus it is our basic goal to develop such type of reactor...[2]

The long term program, which recognized the difficulty of developing breeders, was revised in 1961 and set the goal of fast breeder reactor (FBR) commercialization for the late 1970s. The plan also recommended that the first reprocessing plant be built by 1971.[3] The first plant was completed in 1975 at Tokai.

The 1967 Long Term Program was the most important in setting the nation's long-term nuclear goals. It contained the following elements.[4]
(1) The plan recognized that commercial nuclear development had become reality and that all but one of the commercial reactors in Japan were LWRs licensed from the U.S. The plan also presented a goal for nuclear power development for the first time: 6 GWe (1 GWe=1000 MWe) by 1975, and 30-40 GWe by 1985.

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[2]Japan Atomic Energy Commission, "Basic Long Term Program for Development and Utilization of Atomic Energy," September 6, 1956.

[3]JAEC, "Long Term Program for Development and Utilization of Atomic Energy," February 8, 1961.

[4]See JAEC, "Long Term Plan for Development and Use of Atomic Energy," April 13, 1967. In 1963, JAEC nominated the Heavy Water Reactor (HWR) as the main target for Japanese nuclear development, but the ad-hoc committee established at JAERI was not able to make a final decision on the best coolant. In 1964, after the U.S. passed a law allowing private ownership of nuclear materials for export purposes, the JAEC established another ad-hoc committee on power reactor development. The committee sent a study mission to Europe and the U.S. and published an influential report in 1966. The 1967 long term plan incorporated many of this committee's recommendations.

(2) The program identified FBRs as the main goal of the Japanese domestic nuclear development program, while also recommending concurrent development of the Advanced Thermal Reactor (ATR). It was believed that the ATR, which is a heavy water-moderated and light water-cooled reactor developed by Japan, could be commercialized much sooner than the FBR.
(3) The program also set the goal of closing the "nuclear fuel cycle" through enrichment and reprocessing in Japan.
(4) But it was recognized that plutonium, which is most effectively used in FBRs, may have to be used first in thermal reactors (i.e. ATRs and LWRs) as the commercialization of the FBR would be farther in the future.
(5) Reprocessing at first would be the responsibility of the Japan Atomic Fuel Public Corporation (JAFC), but reprocessing would eventually be carried out by private enterprise.
Based on those decisions, the JAEC called for creation of national projects to develop advanced reactors and nuclear fuel cycle capability. The Power Reactor and Nuclear Fuel Development Corporation (PNC) was created by the Japanese Government as a key organization to implement these important tasks. Although five long-term programs (in 1972, 1978, 1982, 1987 and 1994) have been published, and some important changes have been made during those periods, the basic direction and principles of the plutonium programs have not changed since 1967.

Historical Development

Fast Breeder Reactors (FBRs)

FBR development in Japan was divided into four stages: experimental reactor development, prototype reactor development, demonstration reactor displays, and commercialization. Japan's experimental reactor, JOYO (100 MWth[5]), went critical in 1977 and was converted into a radiation bed for use as a testing facility in 1982. The prototype FBR, MONJU (280 Mwe), began operation in 1994. Both JOYO and MONJU are owned and operated by PNC. The next stage involves building a Demonstration Fast Breeder Reactor (DFBR) which will be owned and operated by the Japan Atomic Power Co.

Japan's FBR development grew rapidly after the PNC was founded in 1967; as a consequence, so did the Japanese nuclear budget. During the 1970s and 1980s, FBR activities accounted for about one-third of the total PNC budget, which was about one-half of Japan's government's entire nuclear budget. By 1991, Japan's FBR budget exceeded the FBR budgets of all other advanced nuclear countries. This picture, however, may be misleading since Japan started its FBR program much later than other nuclear power countries. By the mid-1960s, the U.S. had built five experimental FBRs; the former Soviet Union had three, and the U.K. had one. By the late 1970s, France had built two FBRs (Rapsodie and Phoenix), one of them (Phoenix) about the size of MONJU. By that time, the U.K. had built PFR (250 MWe), and the U.S. had completed the Fast Flux Test Facility (400 MWth). West Germany was at about the same stage as Japan, and had completed the KNK-II (20MWe) in 1977. At that time, Japan's FBR budget was much smaller than that of the others and was well behind all except West Germany.

During the 1980s, however, FBR development programs in other countries except France changed direction. Cost overruns, technical difficulties, proliferation concerns, safety and environmental concerns were the primary causes. The U.S. canceled the Clinch River Breeder Reactor (CRBR, 380 MWe) in 1983. The U.K. and West Germany decided to cancel their demonstration reactors (CDFR and SNR-2 respectively) and formed a joint project with France to develop a European Fast Reactor. France completed Superphoenix (1240 MWe), the world's largest FBR, in 1985. However, Superphoenix had a series of technical problems and operated for fewer than 200 days up to 1993. Germany gave up its prototype FBR, SNR-300, (327MWe) mainly because of political opposition even though construction was completed. The U.K. also decided to stop the operation of the PFR in 1993.

Cost overruns were also responsible for delays in the Japanese FBR programs. In 1979, the construction cost

[5]"MWth" means thermal output in MW. Since thermal efficiency of a typical nuclear plant is about 33%, JOYO's equivalent electric output (MWe) would be about 33 MWe. JOYO, however, is not designed to produce electricity.

of MONJU was estimated to be 400 billion yen which was already about 3 times as expensive as that of a typical commercial nuclear plant[6]. Private utilities agreed to pay 15% of the total cost, i.e. 60 billion yen. However, due to the rising cost of construction materials and more stringent safety standards, the projected costs increased almost 50% to 590 billion yen. Responding to government requests, private utilities finally agreed to pay up to 109 billion yen, or roughly equivalent to the cost of a commercial reactor. As for the DFBR, private utilities are expected to bear the entire financial burden. Based on the MONJU experience, however, private utilities stated that they would be reluctant to order the DFBR if the projected construction cost exceeds 1.5 times that of a LWR.

Plutonium Recycling in LWRs

Japan's interest in plutonium recycling dates back to the 1960s. In 1961, the JAFC sent a group to the U.S. to study plutonium recycling programs and concluded that the U.S. was about to begin commercial use of plutonium fuel. The JAFC quickly responded to the report and contracted with a U.S. company (NUMEC) for a detailed design of a mixed-oxide (MOX) fuel fabrication plant. At that time, the U.S. was encouraging consumer nations to recycle plutonium in order to reduce the demand for enriched uranium. The American plant was completed in 1965 and Japan imported the first 1.5 kg of plutonium from the U.S. Although Japan originally planned to conduct irradiation tests in their research reactors, technical problems forced Japan to depend on U.S. reactors for irradiation testing. The utility industry was also interested in participating in the recycling experiment. The Central Research Institute of the Electric Power Industry (CRIEPI) signed a contract with the Edison Electric Institute (EEI) to participate in EEI's demonstration project.

Although Japan's experience in plutonium recycling in LWRs is limited, Japan gained experience in MOX fuel fabrication through the ATR and FBR projects. By the end of 1970, the JOYO fuel fabrication line (1 ton MOX/y) was completed, as was the FUGEN (ATR prototype) line (10 tons MOX/y) in 1972. Most recently, a plutonium fuel production facility (PFPF), which utilizes the most advanced technologies, was completed in 1988. The PFPF has both a MONJU line (5 tons MOX/y) and a Demonstration ATR (DATR) line (40 tons MOX/y). Japan's cumulative MOX fabrication experience exceeded 100 tons by the end of 1993.

Reprocessing and Plutonium Surplus

Originally, reprocessing was considered necessary to meet the demand for plutonium required for the FBR programs. However, in practice, the pressure for reprocessing was generated by the perceived need to reprocess the accumulation of spent fuel from operating reactors. The first requirement for reprocessing came from the spent fuel from the Tokai-1 Gas Cooled Reactor (GCR), the fuel for which was originally imported from the U.K. However, delay of the Tokai reprocessing plant created uncertainty about the handling of GCR's spent fuel. In 1967, JAPCO concluded a three year reprocessing contract (about 160 tons) with the U.K. Atomic Energy Authority. After reprocessing, the plutonium was to be returned to Japan. This was the beginning of overseas reprocessing and the need for plutonium shipments.

By the mid-1970s, it was clear that there would not be enough reprocessing capacity in Japan to cover the assumed demand for spent fuel reprocessing as nuclear power capacity was expected to grow substantially over the next twenty years. In 1976, JAEC set up a discussion group on the nuclear fuel cycle to plan Japan's fuel cycle activities up to 1995. The group recommended the construction of a commercial scale reprocessing plant (1500 tons/y) which would be built and operated by a private firm primarily supported by the electric utility industry. Until such a plant was completed, the utility industry needed to find reprocessing companies outside Japan. The U.S. had only one nearly complete commercial reprocessing plant by 1976: the Allied General Nuclear Service Barnwell plant (1500 tons/y). However, Carter Administration nuclear policy prevented completion and startup of the plant primarily because of proliferation concerns. In addition, technical and economic problems were emerging in the program and the prospects for commercial reprocessing in the U.S.

[6] A typical nuclear plant (1000MWe) costs about 400 billion yen; thus its unit cost is 0.4¥ billion/MWe. MONJU is only 280 MWe; thus its estimated unit cost was 1.4¥ billion/MWe.

were declining.[7]

As a consequence, Japan came to depend on European companies for reprocessing, COGEMA of France and British Nuclear Fuel Ltd. (BNFL) of the U.K. By the late 1970s, Japanese utilities had made contracts with COGEMA covering 2,200 tons of spent fuel and with BNFL for 2,300 tons.[8] Several characteristics of these contracts are important. First, Japan was one of the largest customers for both BNFL and COGEMA, accounting for about 35% of their total contracts. The only comparable foreign customer was Germany. Because of the cancellation of contracts by other smaller customers, such as Sweden and Italy, Japan's share is now the largest. Second, both BNFL and COGEMA built facilities largely for foreign customers. The capital costs of UP-3 (800 tons/y) for COGEMA and the Thermal Oxide Reprocessing Plant (THORP) (1200 tons/y) for BNFL were largely paid by their customers. In addition, these contracts are basically "take or pay", i.e. customers are committed to pay certain fees regardless of the actual amount of reprocessing. The customers would pay an incremental cost plus a service fee in addition to the basic fee when reprocessing takes place. Third, plutonium and high level radioactive waste (HLW) recovered from reprocessing might have to be returned to customers shortly after the reprocessing (subject to negotiation). Customers might have to pay an additional charge if plutonium or HLW had to remain at the reprocessors' sites. Because of these contractual requirements, Japan was obliged to ship plutonium and HLW from Europe back to Japan. The resulting shipments proved to be controversial. The customers and reprocessors were locked into these contracts with little flexibility. Japan, along with other European customers, had no choice but to depend on both companies since there was no place else to obtain reprocessing services. BNFL and COGEMA thus had nearly "risk free" contracts to build their large scale reprocessing plants.[9]

While short term reprocessing needs have been met by the overseas reprocessors, Japanese utilities have been preparing for their own commercial reprocessing plant since the mid-1970s. Based on the long term program initiated in 1972 which specified the "expectation" of a commercial reprocessing plant after the construction of Tokai to be owned and operated by the private sector, Japanese utilities set up a "Preparatory Commission" for the commercialization of reprocessing and enrichment plants in 1974. But it was after the Carter Administration policy which prevented reprocessing in the U.S. from proceeding that Japanese utilities took serious steps toward the establishment of a domestic reprocessing capability. It is ironic that Carter's policy, designed to discourage development of a "plutonium economy" actually contributed to the Japanese decision to create a domestic plutonium capability.

On June 1, 1979, the Diet passed an amendment to the law regulating nuclear materials to allow the private sector to be engaged in reprocessing. Until then the law only allowed PNC and JAERI to conduct reprocessing. In 1980, Japanese utilities and major industrial companies established the Japan Nuclear Fuel Service (JNFS), a commercial enterprise that was to specialize in reprocessing activities. The JNFS originally planned to build a 1200 tons/y reprocessing plant by 1990. Its construction cost was estimated to be 690 billion yen (at 1979 prices), 80% of which would be financed by borrowing, mostly expected to come from the Japan Development Bank (JDB) at a low interest rate. This plan was confirmed in the 1982 JAEC long term program.

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[7]There were two other commercial plants in the U.S., both of which were closed by mid-70s. General Electric's Midwest Fuel Recovery Plant (300 tons/y) was closed in 1974 and Nuclear Fuel Services' West Valley plant (300 tons/y) was shut down in 1976. The Barnwell plant was also closed when the Reagan Administration rejected federal funding to aid in the completion of the plant in 1983.

[8]Berkhout, F., Suzuki, T., and Walker, W., "Surplus Plutonium in Japan and Europe: An Avoidable Predicament." MITJP 90-10. Massachusetts Institute of Technology, 1990. There are differing estimates for the total contracts; for example, M. Suzuki estimates 1600 tons each for BNFL and COGEMA as quoted in "Reprocessing contracts with UK and France, and spent fuel shipment," in "Questioning the Plutonium," International Conference on Plutonium, Omiya, 1991.

[9]Because of uncertainty in reprocessing contracts beyond the base contracts (after 2002) and in waste management costs, the future viability of reprocessing business has been questioned. See for example, Berkhout, F., and Walker, W., "THORP and the Economics of Reprocessing," SPRU, November 1990.

In 1986, discussion of the next long term program began. It became clear that the demand for plutonium would be much smaller than originally expected, primarily because of delays in the FBR program. JNFS reduced the size of the second reprocessing plant to 800 tons/y, a decision which was confirmed by the JAEC in 1986.[10] Still, there were serious discussions regarding what to do with "surplus" plutonium. In 1984, the JAEC established the "Study Group on Long Term Nuclear Development Strategy." The group estimated that the cumulative amount of plutonium which Japan would recover from spent fuels would be about 75 tons (fissile) by the year 2005, and 100 tons by 2010. The study also estimated that the plutonium demand for ATRs (5 units in total) and recycling to LWRs (10 units) would reach those amounts. The group concluded, therefore, that by the early 2000s, plutonium demand would exceed supply and thus no plutonium surplus would occur.[11] One year later, in 1985, the JAEC's "Discussion Group on Reprocessing" published a seemingly unrelated plan to build 7 ATRs (each 1000 MWe class) and 17 LWRs capable of recycling plutonium by 2010.[12]

In the 1987 long term program, the demand for plutonium was revised again, mainly because of delays in the "supply side" reprocessing projects. According to the 1987 plan, the first commercial reprocessing plant (800 tons/y), to be located at Rokkasho, would start operation in the mid-1990s. The second commercial plant would be built around 2010, although the plan stated explicitly that "the next plant would be built considering the trends in plutonium demand."[13] Although the plan indicated that the demonstration ATR (DATR, 606 MWe) would be built by the mid 1990s, it did not specify how many ATRs would be built in the future.[14] Under the 1987 program, the JAEC scaled back its plan to one DATR and 10 units of LWRs [with 1/3 core of plutonium fuel] by the late 1990s.[15]

As international criticism of the plutonium shipments increased, the JAEC Advisory Committee on Nuclear Fuel Recycling published a new report in August 1991. The report, "Nuclear Fuel Recycling in Japan," [16] is significant for several reasons. First, the report recognized that plutonium is considered "a militarily sensitive material", and clarified that it is "a national principle that Japan will not possess plutonium beyond the amount required to implement its nuclear fuel recycling programs." This is a clear commitment by the JAEC not to have any "plutonium surplus".[17] Second, it updated the estimated amount of plutonium supply/demand figures, showing that there would be no "surplus" until 2010 or beyond. According to the paper, the cumulative supply

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[10]As discussed below, "800 tons/y" was selected mainly because the JNFS decided to employ the French UP-3 plant design (800 tons/y).

[11]Quoted in Kinya Ishikawa, "Genshiryoku Seisaku No Hikari to Kage (Light and Shadow of Nuclear Power Policy,)" Denryoku Shimpo Sha, 1985. p. 126. The detailed discussion of the plutonium surplus during the preparation for the 1987 long term plan can be found in this book as well as Ishikawa's "Genshiryoku Seisaku: 21 seiki he no michi (Nuclear Power Policy: A Road to the 21st Century)", Denryoku Shimpo Sha, 1987.

[12]ibid., p. 128.

[13]JAEC, "(Long Term Program for Development and Utilization of Atomic Energy,)" June 22, 1987, pp. 73-74.

[14]This reflects the non-committal stance taken by the utilities beyond the DATR, mainly because of the high cost of ATRs. See the detailed discussion in Ishikawa's books cited in this study.

[15]JAEC, op. cit., p. 93.

[16]JAEC, Advisory Committee on Nuclear Fuel Recycling, "Nuclear Fuel Recycling in Japan," August, 1991 (tentative translation summary).

[17]A later government document uses slightly softer language. The Ministry of Foreign Affair's paper, "Plutonium: A Renewable Source of Energy," November 1992, said that "Japan scrupulously maintains the policy of not keeping on hand more than the amount of plutonium required for *running stocks*."

by 2010 would be around 85 tons fissile (30 tons from overseas and 55 tons from domestic plants). The Rokkasho plant's operational date was planned to be "at the end of 1990s." Meanwhile, the cumulative plutonium demand would be at that time around 80-90 tons. ATRs (FUGEN and DATR) and FBRs (JOYO, MONJU, and DFBR and succeeding FBRs) would consume about 35 tons. The remaining demand would come from LWR recycling: 2 units [1/4 core] by the mid 1990s, 4 units [1/3 core] by the end of the 1990s, and 12 units shortly after 2000. As can be seen, plutonium scheduled for LWRs and ATRs has been adjusted up or down at will to match the supply that in turn is based on the schedule for reprocessing. It is clear that the plutonium program has been "supply driven" rather than "demand driven."

International Influence

The U.S.-Japan Agreement

Although "indigenous" development is one of the major goals of the nuclear power program, Japanese nuclear development has always been subject to influence from abroad. The U.S. has had the strongest influence under bilateral agreements, since it has been the dominant supplier of both enrichment services and nuclear reactor technologies to Japan.

The first Japan-U.S. agreement for peaceful use of nuclear energy was signed in 1955 and amended in 1958. The 1958 agreement incorporated a safeguards requirement for the first time following the establishment of the International Atomic Energy Agency (IAEA) in 1957. The 1955 agreement required that all spent fuel be returned to the U.S., while the 1958 agreement allowed reprocessing in Japan or elsewhere, but only with U.S. approval. Under the agreement, Japan needed to obtain "prior consent" for reprocessing and for transfer to third countries. This process, the so-called "MB-10" process, was carried out on a case-by-case basis, requiring Japanese private utilities and government agencies to prepare documents for each shipment of spent fuel to Europe for reprocessing. In 1972, the agreement was further amended to include a requirement for "joint determination (by Japan and the U.S.)" to allow startup of a new reprocessing plant, with the condition that the plant had "adequate safeguards arrangement" (Article 8, Item C). This is the clause that gave the U.S. a legal right to intervene in the startup of the Tokai reprocessing plant in 1977 (described below).[18]

In 1978, the U.S. passed a new law, the Nuclear Non-Proliferation Act (NNPA) of 1978,[19] which required the President to renegotiate all existing nuclear agreements to satisfy the more stringent requirements of the NNPA. After long negotiation, Japan and the U.S. finally ratified a new agreement in 1988. That agreement has several clauses with important implications for Japan's plutonium programs.[20]

- Programmatic Approval. Article 11 provided for a new implementing agreement in which "prior consent" can be given at one time for all programs Japan submits for plutonium use. In other words, the agreement allowed "programmatic" rather than case-by-case approval for Japan's peaceful plutonium use. Programmatic consent is to be in effect for the 30 year lifetime of the agreement.

- Tighter control over "sensitive technologies and material". The agreement incorporated more stringent regulations specified by the NNPA.

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[18]Science and Technology Agency, "Kata Fukakusan Hando Bukku (Non-Proliferation Handbook)," Japan Atomic Industrial Forum, 1988 edition.

[19]"Nuclear Non-Proliferation Act of 1978," Public Law 95-242 Sec. 404(a) requires the President to renogiate agreements for cooperation.

[20]"Agreement for Cooperation Between The Government of Japan and The Government of The United States of America Concerning Peaceful Use of Nuclear Energy," 1988. See also Donnelly, W.H., "U.S.-Japan Agreement for Nuclear Cooperation: Monitoring Its Implementation," September 28, 1989, Congressional Research Service, IB88095.

- Tighter regulation over plutonium shipments. The agreement specified tighter physical protection requirements for shipments.

- Broader US influence ("contamination" clause). Article 9 of the new agreement broadened the definition of "U.S. origin materials and technologies." The new definition included the material irradiated (i.e. "contaminated") in a reactor which had been licensed by U.S. manufacturers. This covered almost all plutonium contained in the spent fuel from LWRs, even if the original uranium and enrichment suppliers were not from the U.S.

Thus, the 1988 agreement gave comprehensive approval for Japan's plutonium programs for the following 30 years.[21] However, the U.S. still retained the legal right to intervene, especially with regard to plutonium shipments (described below), although total suspension of the agreement is very unlikely.[22]

Japan has bilateral agreements with other nuclear suppliers such as the U.K., France, Canada and Australia. The former two are the suppliers of reprocessing services and the latter are suppliers of natural uranium. Japan also has a bilateral agreement with China, signed in 1985 which is unique because Japan is in the role of supplier. Japan imposed tougher conditions on China than the U.S. did on Japan, requiring IAEA safeguards for all activities under the agreement. China, which refused to sign the Nuclear Non-Proliferation Treaty (NPT) at that time, had not even joined the IAEA until 1984. China did sign the NPT in 1992, but is not required to accept full-scope safeguards as it is a nuclear weapon state.

Safeguards and Physical Protection

In addition to bilateral agreements, Japan's plutonium programs are governed by multilateral treaties and conventions. The most important are international safeguards against proliferation carried out by the IAEA in the framework of the NPT, and physical protection (PP) which is implemented by each nation in the framework of the International Convention on Physical Protection.

As a non-weapon state member of NPT, Japan is subject to full-scope safeguards (INFCIRC 153), which cover all existing and future nuclear activities. Japan viewed the requirement for full-scope safeguards as a matter of unequal treatment in the treaty, since similar safeguards are not required for nuclear weapon states. That issue was a source of controversy in the debate over treaty ratification; the treaty was finally ratified in 1976, six years after it was signed.[23]

The Convention on Physical Protection was signed in 1980 and became effective in 1987; Japan became a member in 1988. Unlike safeguards, each member nation is responsible for its own PP activities and regulations, while the Convention gives general guidelines that are to be met by the regulations. Before the Convention,

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[21]There was opposition to this agreement in the U.S. Congress, where it was argued that "30 year prior consent was illegal under the NNPA of 1978." There was also strong opposition to the advance approval of plutonium shipments. The Senate Foreign Relations Committee once rejected the agreement by a vote of 15 to 3. However, the resolution to disapprove the agreement was rejected in the Senate in March, 1988 by a margin of 53 to 30.

[22]For example, Article 3 item 2 of the implementing agreement states: "Either party may suspend the agreement...to prevent a significant increase in the risk of nuclear proliferation or in the threat to its national security caused by exceptional cases such as a material breach by the other party etc........"

[23]The Lower House of the Japanese Diet ratified the NPT, but added the following conditions. (1) firm adherence to the Three Non-Nuclear Principles, (2) appeal to nuclear weapon states that they should not use nuclear weapons against non-nuclear weapon states, (3) sincere efforts toward a comprehensive test ban, reduction and abolition of all nuclear weapons, (4) secure nuclear fuel supply, establishment of inspection procedures, securing three principles for peaceful use, and (5) international efforts to promote "nuclear free zones".

the IAEA developed international guidelines for physical protection (INFCIRC 225 Rev) which were originally issued in 1975 and most recently amended in 1989.

In addition to the requirements of the Convention, Japan must satisfy requirements specified by bilateral agreements, in particular the 1988 US-Japan Agreement that has more stringent physical protection requirements than the international Convention. The 1992 plutonium shipment was the first case that was subject to the new physical protection requirements.

The Carter Policy and Plutonium Shipments

Two major cases are illustrative of the nature of international influence on Japan's plutonium programs. One was U.S. President Carter's non-proliferation policy in 1977 which directly influenced the startup and operation of the Tokai reprocessing plant. The other was the controversial plutonium shipments from Europe to Japan which were criticized in the U.S. Congress in both 1984 and 1992. In both examples, Japanese plutonium programs were heavily influenced by external factors that Japan had little power to control.

The Tokai plant was completed in 1975 and a cold test run was conducted in 1976. PNC was planning to conduct a "hot-test" in 1977 and needed "prior consent" from the U.S. for its operation. But, in April 1977, based on its new non-proliferation policy,[24] the Carter Administration asked Japan to adopt, as a condition for the startup, a so-called "co-processing" process in which plutonium would not be completely separated. Japan was not willing to accept the request since, in order to adopt such a process, the plant would have to be redesigned and would require major modification. While the two governments agreed in 1977 that the Tokai plant could operate at limited capacity (99 tons/y instead of full 140 tons/y),[25] the negotiation continued into the more favorably inclined Reagan Administration.[26] A new agreement was reached in October 1981 allowing the Tokai plant to operate at full capacity.

In 1984, when Japan needed "prior consent" from the U.S. for shipping about 190 kg (fissile, 253 kg in total) of plutonium from France, a major debate broke out in the U.S. The result was the inclusion of tougher conditions on plutonium shipments in the 1988 U.S.-Japan agreement. That agreement gave the basic framework for plutonium shipment by *air*, which was originally preferred over the sea shipment. However, Senator Murkowski of Alaska opposed the air shipment as it would require a refueling stop in Alaska. He sponsored an amendment to the 1988 Budget Reconciliation Act that substantially tightened the safety criteria for licensing of the plutonium shipping case by the Nuclear Regulatory Commission. This new requirement led both Japanese and the U.S. Governments to switch to shipment by sea which, however, also faced opposition from some members of the U.S. Congress.[27] Although the shipment was officially approved by the U.S. Government in August 1992, there were several Congressional actions that could have dramatically influenced the shipments or could influence future plans. For example, the Abercrombie-Jones Amendment to the energy bill would "restrict

[24]The new policy stated that the U.S. would postpone indefinitely commercial use of plutonium, reprocessing, and breeder reactor programs and asked other countries to follow. In 1976, President Ford had announced a similar but less explicit policy.

[25]There were other conditions for operation: (i) PNC would postpone the construction of the co-processing facility for two years; (ii) Japan would also postpone the commercial use of plutonium for two years; and (iii) no "major initiatives" would be taken for the commercial reprocessing plant.

[26]President Reagan's non-proliferation policy allowed reprocessing where "little proliferation risk exists."

[27]A letter to the President signed by 19 Congressmen dated August 4, 1988, made the following points: (1) a multi-year approval for sea shipment would violate the Atomic Energy Act of 1954; (2) for future sea shipments, there must first be an "in-depth" analysis of national security risks, (3) Japan was responsible for providing all physical security arrangements; (4) if the U.S. did become involved, all associated expenses must be borne by Japan.

Table 1-1
Summary of major changes in JAEC long term programs

	Old (1987)	New (1994)
Demonstration FBR	Start construction at the second half of the 1990s	Construction will begin shortly after the 2000
Commercial FBR	2020s to 2030	by 2030
Rokkasho Reprocessing	Start operation by mid-1990s	Start operation around 2001
2nd Reprocessing Plant	Startup schedueled for 2010	Decision will be made in year 2010
Spent fuel (S/F)	S/F surpassing the capacity of reprocessing will be stored	S/F will be stored at the site until reprocessing as "energy storage"
MOX recycling in LWRs	Shift to commercial utilization in the 2nd half of the 1990s, possible to load 10 units (1GWe class, 1/3 core)	In the year 2000, 10 LWRs (1/3 core, ~7 GWe) by 2010, over 10 LWRs
MOX fuel fabrication plant	Scheme will be established in the early 1990s	Less than 100 tons MOX/y plant will start after the year 2000, Most of overseas Pu will be fabricated in Europe
FBR fuel Reprocessing	Pilot Plant, with startup at early years of 21st Century	RETF* will start operation after 2000, setting the target date for the pilot plant startup in mid-2010s
Advanced Fuel Cycle R&D	not mentioned	R&D programs for actinide recycling, and proliferation-resistent fuel cycle technologies

* Recycling Equipment Test Facility

Source: JAEC, long term program, 1994.

Table 1-2
Revised Plutonium Supply/Demand Balance

(Tons in fissile plutonium)

	1994-99	2000-2010
Supply		
Domestic*	~ 4	35 - 45
Overseas	(1994-2010 total of about 30 tons)	
Total (1994-2010)		70 - 80 tons
Demand		
FBR, ATR**	~ 4	15 - 20
MOX recycle in LWRs	(1994-2010 total of about 50 - 55 tons)	
Total (1994-2010)		70 - 80 tons

* Tokai plant only during the 1990s, and Tokai and Rokkasho for the period after the 2000.

** MONJU, JOYO and FUGEN for the period before 2000. DATR and DFBR are added for the period after the 2000.

Source: JAEC long term program, 1994.

access to U.S. ports of ships carrying plutonium," and the amendment to the Energy Policy Act of 1992 that required the President to conduct a study of the safety of plutonium shipment by sea. The report on the safety of plutonium shipments was published in 1994 and is discussed below in Chapter II.

French Influence

France is an important locus of foreign influence on Japan's plutonium programs because of its role as a supplier of technology and service, and as a world leader in plutonium development.

Although development of indigenous technology for the entire nuclear fuel cycle was the original goal of PNC, the Tokai reprocessing plant employed French technology. When it was planned in the 1960s, the Japan Atomic Fuel Public Corporation (JAFC) had to look for foreign suppliers that could provide the most economical design because the Tokai plant was considered a commercial plant rather than a research facility.[28] The JAFC concluded a contract with SGN of France in 1966. When the Rokkasho plant was planned in the early 1980s, the situation was similar. In the end, Japan Nuclear Fuel Service (JNFS) opted for French technology for Rokkasho and a design based on the French UP-3 plant which employed a new "continuous dissolver" process. The decision was primarily based on economic rather than technical factors. Japan thereby relinquished an opportunity to develop and design an indigenous reprocessing plant.

As a leader in plutonium development France has necessarily been an important factor in Japanese plutonium programs. Since the U.S. no longer has significant plutonium R&D programs, France has become a more important role model. This may change in the future, for the French state-owned utility company, Electricité de France (EDF), has no firm plan to build an FBR beyond Superphoenix .

Non-proliferation Issues

Before the explosion of a nuclear device by India in 1974, there had been little official attention to the connection between civilian plutonium programs and nuclear weapons.[29] Some studies conducted in the early 1970s suggested that the risks associated with civilian plutonium use could be significant. In 1974, Willrich and Taylor warned of the importance of physical protection of fissile materials, especially plutonium.[30] This and other studies, particularly the Ford Foundation report, led to a change in policy under President Ford, and then a more stringent non-proliferation policy in 1977 under President Carter which directly affected Japan's plutonium programs as noted above.[31]

The general concern over proliferation has grown over the years, especially after the revelations of secret nuclear weapons programs in Iraq and North Korea. Both examples heightened international attention to the control of fissile materials, and the general concern over the linkage between civilian nuclear power technology and nuclear weapons. With the end of the Cold War, the availability of many tons of fissile material (plutonium and highly enriched uranium [HEU]) from nuclear weapons dismantled as part of nuclear disarmament agreements has

[28]The Ministry of Finance opposed public financing of the Tokai plant as a research facility because reprocessing was already considered as a part of the commercial nuclear program. See the detailed discussion in the Interim Report of this project, July 1994, p. 57.

[29]At that time, the U.S. encouraged plutonium use to save uranium resources.

[30]Willrich, M. and Taylor, T., "Nuclear Theft: Risks and Safeguards," Ballinger, Cambridge, MA, 1974.

[31]See Report of the Nuclear Energy Policy Study Group, "Nuclear Power Issues and Choices," Ballinger, Cambridge, MA, 1977.

raised even greater concern about the control of plutonium.[32] In this international environment, it is not surprising that plutonium developments in Japan, such as the 1992 shipment, the startup of MONJU, and the commencement of construction of Rokkasho received intense international attention.

The 1994 Long Term Program and Subsequent Developments

Recent policy developments have slowed implementation of the overall program. The new JAEC long-term program, published in June 1994, incorporated the following significant measures summarized in Table 1-1.

(1) Introduction of an explicit "no plutonium surplus" policy: The 1994 JAEC long-term program officially confirmed the "no-surplus" policy announced in the 1991 report. The JAEC's new program also published an updated plutonium supply/demand balance which revised the 1991 figures slightly downward. Cumulative plutonium production and demand by 2010 are now estimated to be 70 - 80 tons (Table 1-2), instead of the 80 - 90 tons estimated in 1991. As is evident in Table 1-2, about 70% of total demand comes from MOX recycling in LWRs. This suggests that the MOX recycling program is critical in maintaining Japan's commitment to avoid a plutonium surplus. If the MOX recycling program does not move forward as expected, the reprocessing programs would have to be slowed to prevent the creation of a significant plutonium stockpile.

(2) Postponement of the second commercial reprocessing plant and FBR commercialization schedule: One of the more significant aspects of the new long term program was to delay the decision to build the next commercial reprocessing plant until 2010. The 1987 plan called for its startup in 2010. The Rokkasho reprocessing project, though re-confirmed, was also delayed. The new program acknowledges the resulting need for a long-term spent fuel storage program. In addition, the FBR commercialization date was also delayed from 2020 to 2030. The construction schedule of a demonstration FBR (DFBR) was also delayed accordingly. Most recently, in July 1995, the Federation of Electric Power Companies requested the JAEC to cancel the DATR project.[33]

(3) Introduction of "Advanced Fuel Cycle" R&D: The new long term program included an R&D program called "Advanced Nuclear Fuel Recycling Technology." It specified "[that the R&D program] should increase the options of technical selection by pursuing the possibilities of technology to meet diversified needs of future society, including reducing the load on the environment and considering nuclear non-proliferation."[34] The program includes development of new types of fuels such as nitride and metal fuels, as well as recycling of actinides for a "new recycling system based on FBR technology." A special JAEC sub-committee on Nuclear Fuel Recycling has started to work on a development plan for an overall "advanced fuel cycle R&D" program.

(4) Increasing the "transparency" of the program: The new program puts more emphasis on nuclear non-proliferation issues than any previous long-term program, partially because of increased domestic and international concern over Japan's plutonium programs. For example, in a section entitled "Japan's voluntary efforts for nuclear non-proliferation," the program indicates that, "International anxieties concerning Japan's nuclear fuel recycling project have been indicated since the transportation of plutonium by Japan."[35]
Specifically, the JAEC said that Japan will take voluntary measures in addition to the international obligations required by the NPT and other agreements.

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[32]For example, see Scheinman, L. and Fischer, D.A., "Managing the Coming Glut of Nuclear Weapon Materials," Arms Control Today, March 1992, pp. 7-12; and Perkovich, G., "The Plutonium Genie," Foreign Affairs, Vol. 72, No. 3, Summer 1993, pp. 153-165.

[33]"Giving Up the ATR: The Federation of Electric Power Companies Requests Change for Ohma Nuclear Power Plant," Nihon Keizai Shimbun, July 12, 1995, pp. 1 & 3.

[34]JAEC, "Long term program for development and utilization of Atomic Energy," June 1994. Translated in JPRS Report, Science and Technology Japan, JPRS-JST-95-002, 6 January 1995, p. 22.

[35]ibid., p. 15.

Improving the "transparency" of the program is cited as one major policy initiative of the long term program, with the voluntary disclosure of plutonium inventories as an example. In the newly published 1994 annual White Paper on Atomic Energy, the JAEC voluntarily disclosed its own plutonium inventory. The JAEC had done so before in 1993, but as a response to an inquiry by the Diet. Now it is the JAEC's official policy to disclose the inventory on a regular basis.

A second initiative is to participate actively in discussions to establish an international management regime for plutonium and HEU. In July 1993, the STA's Council for an International Plutonium Management System (Headed by Mr. H. Kurihara, Executive Director of the PNC) presented a proposal for an international management scheme for plutonium and HEU. The primary purpose is to improve transparency in the utilization of these materials for peaceful purposes and to ensure appropriate management of the materials from dismantled nuclear weapons. Under the proposal, participants would disclose their plutonium and HEU inventory by "registering" those materials. Registration would be deleted when the plutonium/HEU is loaded into a reactor as fuel (HEU to be diluted into LEU). Participants would disclose their programs and plans to utilize such materials, and related information would be be disclosed to the public as long as it would not negatively affect physical protection requirements. There would not be, however, a formal monitoring capability. The proposal has been discussed with other potential participants and organizations under the auspices of the IAEA.[36]

These changes have, in effect, scaled down the plutonium program, stretched out the construction plans, and opened the program to greater outside scrutiny. The firm commitment to recycling and breeder reactors, however, remains.

[36]Currently, nine countries (U.S., Russia, France, China, U.K., Japan, Germany, Switzerland, Belgium) and one international organization (IAEA) are discussing the idea.

II. INTERNATIONAL PERCEPTIONS OF DIRECT AND INDIRECT PROLIFERATION RISKS

Japan rightly stresses that it gives intensive attention to the physical security of its nuclear programs and to minimizing risks of weapons proliferation. However, Japanese plutonium programs raise significant concerns outside Japan. Some critics are motivated by profound opposition to any form of nuclear power, a view that would be satisfied only by a policy that would close the entire nuclear power program. Other concerns, however, have been raised by observers and analysts who are not opposed in principle to nuclear power. These latter concerns have attracted the attention of nuclear program planners in the public and private sectors in Japan who recognize that the international political environment may become less tolerant of programs that appear to threaten safety or to increase the danger of nuclear weapons proliferation.

The risks of plutonium proliferation or diversion vary significantly depending on many factors such as the form of plutonium used or stored (metal, oxide powder, fabricated fuel, spent fuels), the nature of ownership (nuclear weapon states, non-NPT countries), the location (storage, being transported) and the quantity involved. In addition, risks are often *perceived* differently depending on differing political and technical judgments about the benefit of plutonium and the dangers of proliferation or diversion. There are two kinds of potential proliferation or terrorism risks associated with Japan's plutonium programs. One is the direct threat of diversion by the Japanese Government or by sub-national groups within Japan or abroad intended for weapons or terrorist purposes. The other is the indirect effect of implicitly encouraging, or setting a precedent for, programs in other countries that could lead to greater danger of proliferation or terrorism.

There are several dimensions to be considered:

A. Demonstration effect
B. Plutonium stockpiles
C. Protection against diversion for weapons or terrorism
D. Weapons options
E. Plutonium shipments

A. Demonstration Effect

The most important issue is the possibility that the very existence of Japan's program, especially at a commercial scale requiring a significant commitment of scarce resources, will be cited as a precedent or justification, genuine or insincere, for other nations to follow suit with their own reprocessing and breeder programs. Other nations may not give the equivalent attention to safety and proliferation considerations that Japan has shown, or have the capability to do so. In fact, Japan's program is currently being cited as a precedent by others, especially in East Asia. And, Japan 's commitment to plutonium makes it politically difficult for the Government to question or oppose programs in other nations.

A recent report (1995) of the Council on Foreign Relations in the U.S. provides a typical example of such a concern:

> "[the countries pursuing a plutonium fuel cycle]... must recognize that in current and projected market conditions their refusal to abandon planned plutonium separation or use programs *legitimizes* an activity that is extremely dangerous from a proliferation standpoint and for which there is no current or foreseeable economic rationale."[1] (emphasis added)

There are, in fact, already signs that Japan's program (or Japan's right to pursue such programs) is being used as a precedent for others, especially in East Asia. South Korea is the most visible example.

With limited indigenous energy resources, the Republic of Korea has been aggressively developing nuclear

[1]Report of an Independent Task Force on Nuclear Proliferation, "Nuclear Proliferation: Confronting the New Challenges," sponsored by the Council on Foreign Relations, 1995, pp. 27-28.

programs.[2] Chung-Taek Park, Director of the Technology Forecast and Survey Division of the Ministry of Science and Technology, wrote in 1992 that the nuclear power program of the Republic of Korea had made good progress towards "creating an independent, indigenous capability of design [in order to] build and operate nuclear power plants." The report continues to explain that in 1987, the South Korean nuclear program entered a "technological self-reliance oriented period."[3] Park argued that in order to make another "quantum leap forward" in the nuclear industry, Korea needs to acquire more "high technologies such as NSSS (Nuclear Steam Supply System) design and manufacturing, fuel reprocessing technologies, next generation reactors."[4] Park then complained that Korea will face obstacles in achieving these objectives "due to the technological hegemony of the advanced countries."[5]
y He specifically cited the example of the Carter administration's denial of technology transfer from France to South Korea in the late 1970s.

These sentiments seem to be intensifying, especially in the light of the suspected nuclear weapons programs in the Democratic People's Republic of Korea (North Korea). North Korea and South Korea signed the Joint Declaration on the Denuclearization of the Korean Peninsula in December 1991, which prohibited both countries from possessing nuclear reprocessing and enrichment facilities, while allowing both to be engaged in the peaceful use of nuclear power.[6] Since then, however, there has been increasing criticism of the Declaration. For example, Kim Taewoo, Director of Policy Analysis at the influential Korean Institute for Defense Analyses, wrote (1993):

> "..The two parts (of the Declaration), ironically, are not only contradictory but will even work against each other because enrichment and reprocessing are intrinsically peaceful technologies that South Korea needs very much for a better use of peaceful atomic energy."[7]

Kim complains about double standards in U.S. policy dealing with plutonium programs in Japan and in South Korea. Specifically citing the 1988 U.S.-Japan Agreement on peaceful use of nuclear energy, Kim stated "[the programmatic approval of Japan's plutonium programs] dramatically contrasts with the U.S. policy towards the Korean peninsula."[8] Chong Chea-mun, Chairman of the National Assembly's Foreign Affairs Committee, also wanted to review the 1991 Declaration, saying that "we know that we could generate nuclear power at lower cost if we have [sic] reprocessing facilities...and we cannot continue to depend on foreign countries for nuclear

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[2]As of December 1994, S. Korea had 9 reactors in operation with a capacity of 7.6 GWe, with 7 more units (6.1 GWe) under construction. The Government and the Korea Electric Power Company (KEPCO) plan to build 7 more units reaching a total capacity of 20.4 GWe by 2006. Nuclear power currently supplies about 40% of total power production, and its share is expected to increase to 48% by 2006. See Chung, B.H., Jeon, J.P., "Nuclear Power Development in Korea," Proceedings of the 9th Pacific Basin Nuclear Conference, Sydney, Australia, 1-6 May, 1994. vol. 1, pp. 85-90.

[3]Chung-Taek Park, "The experience of nuclear power development in the Republic of Korea: Growth and Future Challenge," Energy Policy, Vol. 20, No. 8, August 1992, pp. 721-734.

[4]ibid., p. 733. As of 1992, breeder reactors had only a small share (about 10%) of the total nuclear budget. (OECD/IEA, "Energy Policies of the Republic of Korea," 1992).

[5]ibid., p. 734.

[6]Article 2 of The Joint Declaration says, "South and North Korea shall use nuclear energy solely for peaceful purposes," while Article 3 says, "South and North Korea shall not possess nuclear reprocessing and uranium enrichment facilities."

[7]Kim, Taewoo, "The United States and North Korea: A South Korean Perspective," Prepared for a Symposium on "The United States and North Korea: What Next?," sponsored by the Carnegie Endowment for International Peace, Washington, D.C., November 16, 1993.

[8]ibid., p. 14.

fuel."[9]

Meanwhile, the Korean Electric Power Company (KEPCO), the only utility company in South Korea, faces problems with spent fuel and radioactive waste management, difficulties common to all nuclear utilities. Officially, South Korea has not committed to any particular back-end option or to a definite plan for final waste disposal.[10] KEPCO, therefore, has to deal with spent fuels until such policies are developed. According to the OECD/IEA study (1992),[11] cumulative amounts of spent fuel, which were 910 tons in 1990, are expected to increase to 3,800 tons in 2000, 7,000 tons in 2010 and 19,000 tons in 2025. Anticipating that on-site reactor storage capacities will run out at the end of the century, KEPCO recently announced a site to build an Away-From-Reactor (AFR) storage facility (3,000 tons capacity) at Kurupdo.[12] However, there has been political opposition at the possible waste disposal sites, and it is not certain whether the AFR project can proceed as planned.[13] It has been reported that KEPCO, as a result, has been contacted by reprocessing companies in Europe and even by Russia. It would not be surprising if KEPCO eventually makes a request to the U.S. similar to that made by Japanese utilities during the 1970s: to ship spent fuels abroad for reprocessing as a way of at least postponing the waste management problem. It would be difficult for the U.S., which has a legal right to approve or disapprove such a shipment, to deny approval for South Korea while condoning similar programs in Japan.

Russian and Chinese plutonium plans are also of concern. Russia, which has already built its reprocessing plants and fast breeder reactors, does not yet have a substantial civilian plutonium program. However, officials of the Russian Ministry of Atomic Energy (MINATOM) have repeatedly expressed their strong interest in using plutonium, including plutonium from dismantled nuclear weapons as nuclear fuel since it is a "valuable energy resource for the future nuclear power engineering."[14] Although Russia joined with the U.S. in agreeing to shut down plutonium production reactors by 2000,[15] reprocessing plants are excluded from the agreement. Currently Russia has one reprocessing plant (RT-1) at "Mayak" with full capacity of 400 tons/y. The plant, currently operated at 100 tons/y, is now producing a maximum of 2.5 tons of plutonium annually. The next reprocessing plant (RT-2) is expected to be much larger (1,500 tons/y) and is scheduled to start operation around 2005, but construction has not yet started. There is only one operating fast reactor in Russia,[16] the BN-600 (600 MWe), currently fueled with medium-enriched unranium. Construction of a demonstration fast reactor,

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[9]Quoted in Harrison, S., "A Yen For The Bomb," Washington Post, October 31, 1993. Harrison also wrote that Korean officials say once Korea is unified "it will insist on the right to reprocess on the same terms as Japan."

[10]Comments made at the 28th JAIF annual meeting in Tokyo by Lee Chang-Kun, Research Fellow at the Korean Atomic Energy Research Institute, April 1995. See Atoms in Japan, April 1995, p. 25.

[11]OECD/IEA, "Energy Policies of the Republic of Korea," 1992.

[12]Genshiryoku Sangyo Shimbun, January 12, 1995.

[13]Nucleonics Week, June 2, 1994, p. 15.

[14]Kudriavtsev, E.G., "Plutonium Accumulation and Utilization in Russia," Proceedings of the International Workshop on "Nuclear Disarmament and Non-Proliferation: Issues for International Actions," co-sponsored by Tokai University, Princeton University and the Federation of American Scientists, March 15-16, 1993, Tokyo, Japan, pp. 102-108.

[15]"Agreement between the Government of the U.S.A. and the Government of the Russian Federation concerning the shutdown of plutonium production reactors and the cessation of use of newly produced plutonium for nuclear weapons," Washington, D.C., June 23, 1994.

[16]Another fast reactor, BN-350 (150 MWe) is operating in the former Soviet Union, in Kazakhistan, in part for desalination purposes. Current Russian plans to use plutonium do not appear to include the BN-350.

BN-800 (800 MWe) was begun in 1984, but was halted in 1987 as a result of environmental protests and apparent funding limitations.[17]

MINATOM considered utilization of plutonium fuel in BN-600, but concluded that it was "problematic" to license it for MOX fuel since its core was designed to use uranium fuel.[18] MINATOM is therefore currently planning to use most of its plutonium stocks in MOX fuel in LWRs (VVER-440, VVER-1000) and possibly in BN-800 if it is built.[19] Without such MOX recycling programs, it is estimated that total plutonium stocks, excluding materials from dismantled nuclear weapons, could increase from the current 30 tons to 60 tons total by 2005.[20]

China, another nuclear weapon state that has not yet established civilian plutonium programs, has recently announced its intention to build reprocessing plants and FBRs in the future. According to Donghui (1995),[21] Chief Engineer at the Chinese National Nuclear Corporation since 1987, China's back end fuel cycle strategy has as its goals:

- Utilizing nuclear resources in full;
- Reducing the costs of uranium mining, processing and enrichment;
- Reprocessing spent fuel from nuclear power plants (mainly LWRs);
- Minimizing radwaste;
- Developing a fast neutron reactor; and
- Vitrifying high level liquid waste.

The decision has been made to build a multi-purpose reprocessing plant, scheduled to begin operation at the beginning of the next century. A large reprocessing plant (400 or 800 tons/y) would be built during the 2010s. Donghui also stated that China has been conducting R&D on FBRs since 1987 and that it is planned that an experimental fast reactor (25 MWe) will also be completed at the beginning of the next century. In addition, China is considering a MOX fuel demonstration facility.[22]

China and Russia, unlike South Korea, are not required to accept IAEA safeguards for their nuclear activities except where bilateral agreements may require them to do so. It is not likely, therefore that all their plutonium programs will be under IAEA safeguards in the foreseeable future unless nuclear weapon states change their current policy. It will be difficult, as a result, to assure the international community that both physical security and material accounting are properly executed in all plutonium programs.

The rationales that South Korea, Russia and China are citing for their plutonium programs are strikingly similar to those argued by Japan. It would be tempting for Japan to encourage reprocessing and breeder reactors in these or other countries as a way to dilute the criticism of Japan's program, and along the way develop a commercial market for Japanese technology. But if Japan sends signals that other countries should join Japan to proceed to a plutonium economy, international attention would focus on Japan as taking a "leading role" in promoting a plutonium economy in other parts of the world, with a resulting increase in physical and proliferation danger. It is possible, of course, that these or other countries would proceed with their own

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[17]Norris, R., "The Soviet Nuclear Archipelago," Arms Control Today, January/February 1992, pp. 24-31.

[18]Kudriavtsev, E.G., op. cit.

[19]Kudriavtsev, op. cit., and Bukharin, O., "The Structure and the Production Capabilities of the Nuclear Fuel Cycle in the Countries of the Former Soviet Union," The Center for Energy and Environmental Studies, Princeton University, Report PU/CEES 274, January 1993.

[20]Kudriavtsev, op. cit. p. 103.

[21]Sun Donghui, "Back End of Nuclear Fuel Cycle in China," presented at the 28th Japan Atomic Industrial Forum (JAIF) Annual Conference, April 10-12, 1995.

[22]ibid.

plutonium programs regardless of what Japan does. However, the presence of a large, approved program in Japan, with similar public rationales, would make it more difficult for the international community to discourage programs in other nations that could pose significant, and perhaps larger, proliferation or diversion risks.

B. Plutonium Stockpiles

Concern over the accumulation of separated plutonium from civilian nuclear programs had been raised well before the current debate over the management of fissile materials derived from weapons, but the attention to weapons-grade plutonium has served to increase that concern significantly.[23] Albright et. al. pointed out that the cumulative amount of separated plutonium could exceed the amount of military plutonium stocks held by the superpowers by 2000.[24] A National Academy of Sciences study that called "the existence of this surplus material [weapons-grade plutonium]... a clear and present danger to national and international security," also said that "further steps should be taken to reduce the proliferation risks posed by *all* of the world's plutonium stocks, military and civilian, separated and unseparated."[25] In September 1993, President Clinton's new nuclear non-proliferation policy indicated that the U.S. will seek to "eliminate where possible the accumulation of stockpiles of HEU and plutonium."[26] The new policy also said that the U.S. will "explore means to limit the stockpiling of plutonium from civil nuclear programs" and "does not encourage the civil use of plutonium." The study cited earlier by the Council on Foreign Relations (1995) also stated that the "[plutonium fuel cycle] adds to plutonium stockpiles for which there is currently no acceptable disposal option."[27] In 1992, William Dircks, then Deputy Director General of the IAEA, warned that "the excess of plutonium from civilian nuclear programs poses a major political and security problem worldwide."[28] The Stockholm Peace Research Institute also published a book by European-American experts on the world inventory of plutonium.[29]

Of course, all of Japan's plutonium is under IAEA full-scope safeguards and thus all accounted for. Although there are some concerns about "safeguardability" of bulk-handling facilities (discussed later), the potential risks associated with Japanese plutonium stockpiles are less threatening than stockpiles in countries in which there is not full accounting, as in Russia.[30] And, the quantity in Japan is still relatively small compared to those

[23]von Hippel, F., Miller, M., Feiveson, H., Diakov, A., and Berkhout, F., "Eliminating Nuclear Warheads," Scientific American, August 1993.

[24]See Albright, D., "World Inventories of Plutonium," paper presented to the Conference on International Terrorism: The Nuclear Dimension, June 24, 1985 and later included as an Appendix in Leventhal, P. and Alexander, Y., eds., "Nuclear Terrorism: Defining the Threat," Pergamon-Brassey's International Defense publisher, 1986. Albright, D. and Feiveson, H., "Why Recycle Plutonium?", Science, vol. 235, 27 March 1987, pp. 1555-1556.

[25]National Academy of Sciences, Committee on International Security and Arms Control, "Management and Disposition of Excess Weapons Plutonium," Executive Summary, Washington, D.C., 1994.

[26]Fact Sheet, "Non-proliferation and Export Control Policy," White House, September 27, 1993.

[27]Report of an Independent Task Force on Nuclear Proliferation, op. cit. 1995, p. 28.

[28]William Dircks, "Nuclear Fuel Recycling-The IAEA Perspective," Speech presented at the 25th Annual Meeting of the JAIF, April 13, 1992.

[29]Albright, D., Berkhout, F., and Walker, W., "World Inventory of Plutonium and Highly Enriched Uranium 1992," Oxford University Press, 1993.

[30]For security problems of fissile materials in Russia see, for example, Cochran, T., "Nuclear Weapons and Fissile Material Security in Russia," Testimony before the Committee on Foreign Affairs, Subcommittee on International Security, International Organizations and Human Affairs, June 27, 1994.

in weapons states. The U.K. had, for example, 38.5 tons of plutonium stock as of March 1993, compared to Japan's 10.8 tons (4.2 in Japan) at that time.[31] Still, the concern over growing stocks of plutonium continues.

One set of concerns centers on comparisons between reactor-grade and weapons-grade plutonium. Plutonium typically recovered from spent civilian fuel has a lower content (about 70%) of fissile plutonium (60% Pu-239, 8% Pu-241)[32] compared with "weapons-grade" plutonium which has more than 90% fissile content. Japanese experts have argued that since the Japanese plutonium would be "reactor-grade" only, the proliferation concern is misguided. For example, Ryukichi Imai, former Ambassador At Large on Disarmament to the U.N., wrote in a recent paper (1995):

> "...It has long been known that reactor-grade plutonium can be made into an explosive nuclear device. It is also known that such devices are unfit to be taken seriously as weapons....No nuclear facility in Japan is capable of producing hundreds of kilograms of weapons-grade plutonium...It is thus disturbing that those who publicize their concern about Japan's nuclear arsenal possibilities.. are often not well-informed about the basic technical ingredients of nuclear armament."[33]

However, according to others, the distinction between reactor and weapons grade plutonium is not sufficient to defuse the problem. It has been amply demonstrated that reactor grade plutonium can be used not only for a crude explosive device, but for a reliable nuclear weapon. The NAS clearly stated:

> "..Using reactor-grade rather than weapons-grade plutonium would present some complications. But with relatively simple designs such as that used in the Nagasaki weapon, which are within the capabilities of many nations and possibly some sub-national groups, nuclear explosives could be constructed that would be assured of having yields of at least 1 to 2 kilotons. Using more sophisticated designs, reactor-grade plutonium could be used for weapons having considerably higher minimum yields."[34]

Other concerns about the dangers of a plutonium stock have led to some direct and indirect criticism of Japan's plutonium programs.[35] In response to that criticism, as noted earlier, Japan introduced a "no plutonium surplus" policy in 1991 and reconfirmed this policy in 1994.[36] Japan also allowed greater transparency of its plutonium programs by voluntarily disclosing the inventory of plutonium for the first time in the 1994 annual White Paper on Atomic Energy. Japan's pledge to balance supply and demand of plutonium, hence to avoid a stockpile, is an important step. In effect, Japan recognizes the undesirability of a stockpile by its pledge not to accumulate one. Following up the policy, PNC has suggested that MONJU operate as a non-breeder after the experimental breeder demonstration period.[37] And, Japan has postponed the second commercial reprocessing

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[31]"Seventh Annual Plutonium Figures Published," U.K. Department of Trade and Industry, 1 March 1994. The 38.5 tons include 1.5 tons either owned by BNFL or its foreign customers. The rest is owned by British electric utilities (Nuclear Electric and Scottish Nuclear, Ltd.).

[32]See Berkhout et al, "Disposition of Separated Plutonium," Science and Global Security, 1992, Vol. 3, table 3, p.10. The higher the burnup rate, the lower the fissile content.

[33]Imai, R., "Post-Cold War Nuclear Non-Proliferation and Japan," included as background document #3, in Report of the U.S.-Japan Study Group on Arms Control and Non-Proliferation After the Cold War, "The United States, Japan, and The Future of Nuclear Weapons," co-sponsored by The Carnegie Endowment for International Peace and the International House of Japan, 1995.

[34]NAS, op. cit., 1994, p.4. See also Mark, J.C., "Explosive Properties of Reactor-Grade Plutonium," Science and Global Security, Vol. 4, No. 1, 1993, pp. 111-128.

[35]See Walker, W., and Berkhout, F., "Japan's Plutonium Problem - and Europe's," Arms Control Today, September 1992, pp. 3-10; and Chow, B., and Solomon, K.A., "Limiting the Spread of Weapon-Usable Fissile Materials," National Defense Research Institute, Rand Corporation, November 1993.

[36]See Chapter I for more detailed discussion.

[37]Asahi Shimbun, April 21, 1992.

plant following the Rokkasho plant. These policy initiatives are not likely to settle the issue completely for several reasons. First, MOX fuel demand for LWRs is artificial, in the sense that it can be adjusted up or down at will (see Chapter I). Because of the commitments made to the European reprocessing companies and possibly to the operation of the Rokkasho plant, the amount of plutonium produced will be supply-driven rather than driven by demand for fuel. Second, while Japan may be able to eliminate plutonium stockpiles over the long term by matching demand to the total plutonium to be obtained from reprocessing, a substantial stockpile may occur along the way if MOX in LWRs or breeder programs are delayed. Third, in the steady state, substantial amounts of plutonium may be necessary as "running" stock, providing in effect a stockpile until actual use. In fact, according to the JAEC White Paper (1994), the "inventory" of separated plutonium has been increasing rapidly. As of December 1993, the total inventory of separated plutonium owned by Japan was 10.8 tons, with 4.6 tons in Japan and 6.2 tons in Europe.[38] In 1992, the total inventory was 6.4 tons, with 2.3 tons in Japan and 4.1 tons in Europe.[39] Table 2-1 summarizes plutonium inventories.

The very existence of this stock could be used as a justification for other countries in the region to move towards overt or clandestine nuclear weapons development programs and/or civilian plutonium programs, citing the real or assumed fear that Japan's plutonium stocks could become the basis of a Japanese weapons program that would be a threat to them. For example, according to Harrison, both North and South Korea may see a "potential military threat in Japan's plutonium stockpiling program."[40] It was reported in 1992 that North Korean officials were suspicious of Japan's fuel cycle capabilities and said that if there was any nuclear threat it comes from Japan.[41] Although no official concern has been expressed by the South Korean government, Kim said that "Japan's growing nuclear potential is objectively acknowledgeable and now drawing particular attention on the part of the South Korean intellectuals, if not on the part of decision makers."[42] Kim also characterized Japan's nuclear policy as an "asymptotic strategy," which refers to "a sort of multi-purposed nuclear policy implementation process through which a nation, without having or revealing any military intention, proceeds to acquire all of a nuclear capability except possession of nuclear warheads themselves."[43]

C. Protection Against Diversion for Weapons or Terrorism

Japan has been meticulous in observing international safeguards and physical protection standards. But, the effectiveness of those systems in the context of large-scale plutonium use has not been demonstrated. Japan argues that the existence of the Rokkasho plant will allow further development and testing of safeguards for plutonium. This argument, however, is diminished by the possibility that increases in plutonium stocks, more transfers of fissile materials between countries, the rise in volume of plutonium transport and of complexity of the system, and the implicit encouragement of programs in other countries, may in fact put in question the adequacy of physical protection and of the international plutonium safeguard system. Timing is important. Until there are reliable means for safeguarding large-scale plutonium use, such programs will raise significant international concern.

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[38]JAEC, Annual White Paper, op. cit., 1994. The 4.6 tons of plutonium in Japan includes 1.5 tons transferred from France in 1993.

[39]Science and Technology Agency, response to a question raised at the Diet Session, October 1993. The figures released then were fissile plutonium only. The above numbers were estimated based on the amount of fissile plutonium, assuming the fissile plutonium is about 70% of the total.

[40]Harrison, S. op. cit.

[41]"Newsbrief," Programme for Promoting Nuclear Non-Proliferation, Southampton, U.K., Vol.. 17, Spring 1992, p. 11.

[42]Kim, Taewoo, op. cit., p. 14.

[43]ibid, p. 18 (footnote).

Table 2-1
Inventory of Separated Plutonium of Japan

(tons)*

	Domestic	In Europe	Total
1993	4.6 tons*	6.2 tons	10.8 tons
1992	2.3 tons	4.1 tons	6.4 tons

Note:

* For 1992, the numbers originally published by the Science and Technology Agency were expressed in fissile plutonium only. They are 1.6 tons in Japan and 2.9 tons in Europe. The above numbers assume fissile content is about 70% of total amount.

** 4.6 tons include 1.5 tons of plutonium transferred from France in 1993. Thus the net increase from domestic reprocessing was 0.8 tons during the year 1993.

Source: Science and Technology Agency (1992), Atomic Energy Commission (1994)

These problems may be more acute in a bulk-handling facility. The purpose of IAEA safeguards (SG) is not only to prevent the diversion of nuclear materials, but to deter diversion through the ability to "detect" diversion in a "timely" fashion.[44] The effectiveness of safeguards critically depends on the quantity of materials involved. The larger the facility, the more difficult for the SG system to detect small amounts with a high degree of confidence.[45] The Rokkasho reprocessing plant (800 tons/y) will be the first such facility in a non-nuclear weapon state.

The critical figures here are "Significant Quantity (SQ)" and "Material Unaccounted For (MUF)". SQ is defined by IAEA as "the appropriate quantity of nuclear material for which the possibility of manufacturing a nuclear explosive device cannot be excluded," and the current SQ for plutonium is 8 kg.[46] MUF is considered to be a measurement error in the material accounting system. If MUF is assumed to be about +/- 1% of total output, annual inspection of the Rokkasho plant would result in about 72 kg/y (total) of plutonium MUF (assuming spent fuel contains 0.9% plutonium). Thus, MUF is already 9 times SQ. With 95% confidence (5% false alarm probability), the detection minimum would be 3.29 times the MUF. In other words, 237 kg/y is the minimum detectable amount, i.e. about 30 times SQ. In addition, since weekly output of the Rokkasho plant would be about 250 kg, yearly inspection is not likely to be able to detect any diversion on a timely basis. Under current practice, the IAEA needs to bring a sample to Vienna headquarters for analysis as part of a rather time consuming process. Even if a significant discrepancy is detected, it would take too long to determine whether it is a "false alarm" or a "diversion". In summary, the goal of IAEA safeguards ("timely detection") may not be met by the existing safeguards system for a bulk-handling facility like Rokkasho.

In order to address this issue of safeguards, Japan sponsored and participated in an international project, known as "LASCAR", with the IAEA and the U.S.[47] The project concluded in 1990 that a reprocessing plant of this size can be adequately safeguarded by using a more advanced safeguards systems. One of the key features of the advanced system is so-called "Near Real Time Accountancy" (NRTA), which would conduct weekly instead of yearly material measurements. Sampling tests on-site are also planned. Since weekly output is about 250 kg (with annual throughput of 7,200 kg), the minimum detectable amount can be brought down to about 8 kg. Another measure to enhance the SG system is to increase reliance on containment and surveillance (C/S). Specific measures include installation of cameras to provide surveillance of both the spent fuel pool at the reprocessing plant and the transfer of such fuel to the front-end of the main chemical process. This would enable inspectors to detect attempts to process undisclosed spent fuel in the plant. Another measure, placing seals on the storage tanks, is also expected to improve detection capability. The introduction of NRTA combined with C/S should improve the credibility of the SG system.

An independent analysis of advanced SG systems for a bulk-handling facility by Miller arrived at similar conclusions, but with some significant reservations. He argued that the efficiency of NRTA in detecting a "protracted" diversion of plutonium, i.e. diversion of a small amount of plutonium per week whose cumulative total over many weeks could exceed SQ, is not certain. Second, implementation of NRTA would be both very time consuming and intrusive, which could provoke opposition from plant operators. Third, while the benefits

[44]The technical objective of safeguards is "the timely detection of the diversion of significant quantities of nuclear material from peaceful nuclear activities to the manufacture of nuclear weapons or other explosive devices or for purposes unknown and deterrence of such diversion by risk of early detection." from IAEA Safeguards: An Introduction, IAEA, IAEA/SG/INF/3, 1981, p. 12.

[45]See for example, Scheinman, L., "The International Atomic Energy Agency and World Nuclear Order," Resources for the Future, 1987.

[46]IAEA Safeguards Glossary, 1987 edition, IAEA, IAEA/SG/INF/1 (Rev.1), 1987, p. 23.

[47]As of the end of 1992, Japan had 48 projects with IAEA on safeguards (called "JASPAS"), and half (24 projects) were with PNC. 38 of the 48 projects were already completed. PNC received a special award from International Society of Nuclear Materials Control for its contribution to improving the safeguards and material accountancy systems.

of C/S measures are real, they cannot substitute for NRTA in a quantitative way, since "no one has figured out a logical way of quantifying this benefit." Fourth, more accurate measurements of the plutonium content of waste streams, in particular of the hulls and sludge, would be required. And finally, and most importantly, Miller argued that even if all above measures could work effectively, further improvement of the safeguards system is desirable since the risk of "sub-national" diversion could still be significant. Based on that analysis, he concluded:

> "In sum, technical measures...could lead to a significant improvement in the effectiveness of international safeguards at large plutonium-handling facilities. Implementation of such measures would increase public confidence in the ability of the IAEA to minimize the risks of the use of plutonium in nuclear fuel cycles. Until these measures can be implemented *and* demonstrated, it would be prudent to limit plutonium use to research, development, and demonstration projects."[48]

The most recent analysis of this subject was carried out by the Office of Technology Assessment (OTA) which also concluded:

> "..even the new NRTA system may not be able to measure material flows and inventories accurately enough to detect the absence of as little as one bomb's worth of plutonium per year...To date, the IAEA has not considered the possibility that it may be unable to safeguard large facilities such as the Rokkasho reprocessing plant, but neither has it been able to demonstrate that it can."[49]

Furthermore, there are questions about the adequacy of the definition of SQ. Cochran and Paine of the Natural Resources Defense Council claim in a recent report that the current IAEA definition of SQ is "outdated" since only 1 to 3 kg of weapons-grade plutonium is necessary to create a nuclear explosive device with current sophisticated technologies.[50] The above OTA report also notes that many analysts agree that the current "official" thresholds are probably higher than would be needed by nations attempting to make even their first nuclear explosive.[51] On February 8, 1994, the U.S. Department of Energy declassified a document which confirmed that 4 kg of plutonium are sufficient to make a nuclear weapon.[52] Lowering the SQ would require greater inspection efforts of the IAEA and could result in a significant increase in the financial burden.[53]

Will commercial reprocessing undermine the international safeguards system? This uncertainty in the safeguards system does not necessarily suggest that there is a serious threat of diversion at the Rokkasho plant. In fact, the credibility of a nation's commitment to a peaceful nuclear power program is based on an overall judgment of that nation's seriousness of purpose. In this context, the difficulty of safeguarding a bulk-handling facility such as the Rokkasho plant will not alone undermine Japan's overall non-proliferation credibility. However, measures that appear to be adequate in Japan may not be enough to instill confidence in the activities of other countries. If others, without comparable commitment to their safeguards systems, follow the Japanese example and build large reprocessing plants, the credibility of the entire safeguards system could be undermined. This would be especially so if the countries that did so were suspected of harboring an intention to acquire material for nuclear weapons.

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[48]Marvin Miller, "Are IAEA Safeguards on Plutonium Bulk-Handling Facilities Effective?", Nuclear Control Institute, August 1990.

[49]OTA, "Nuclear Safeguards and the International Atomic Energy Agency," Summary, April 1995, pp. 3-4.

[50]Cochran, T., Paine, C., "The Amount of Plutonium and Highly Enriched Uranium Needed for Pure Fission Nuclear Weapons," Natural Resources Defense Council, 22 August 1994.

[51]OTA, op. cit., p. 11.

[52]Unclassified excerpt from U.S. DOE, classification bulletin WNP-86, February 8, 1994. This statement does not necessarily suggest that SQ should be set at 4 kg, since SQ makes allowance for material loss in processing.

[53]The IAEA recently disclosed a new program called "93+2" which is intended to improve cost-effectiveness of the safeguards system and to improve detection capability of clandestine programs. See IAEA, "Strengthening the Effectiveness and Improving the Efficiency of the Safeguards System," 1995.

This conclusion suggests that it would be desirable if the Rokkasho plant were treated as a demonstration plant to help design an effective international safeguards system. The recent incident at the Tokai MOX fuel fabrication plant, in which 70 kg of "hold-up" was reported, indicates that testing and demonstration of a safeguards system is essential before full-scale commercialization.[54]

D. Weapons Options

Although there have been expressions of concern outside Japan about Japanese weapons intentions, there is no evidence that Japanese plutonium programs were developed to enhance the ability of Japan to build nuclear weapons. In fact, the existence of a large-scale reprocessing plant has only limited effect on the country's nuclear weapons options. Japan now has the fissile material and technical expertise to produce a significant number of nuclear weapons in a brief time if it were to choose to violate international safeguards. The presence or absence of a commercial plutonium facility does not change that situation, though it would permit a larger diversion of fissionable material for any given threshold of confidence, standard of observation, or level of monitoring technology. However, the apparent relationship of the reprocessing program to a weapons option has contributed to foreign apprehension about Japanese intentions with respect to nuclear weapons. That concern, which is at a low level today, would likely grow over the years as plutonium operations grow.

Suspicions about possible Japan's intentions to acquire nuclear weapons and about Japanese capability to produce weapons have persisted despite repeated Japanese denials and the existence of legal/political constraints. However, the suspicions were mostly a result of occasional comments or statements made by politicians or government officials. Only recently have Japan's plutonium programs been the subject of such suspicions, possibly fueled by the alarm over the secret nuclear weapons program of North Korea.

For example, Harrison stated that although Japan's plutonium program is primarily motivated by the national desire for energy independence it "also reflects sentiment in favor of keeping the nuclear weapons option open as insurance against unpredictable changes in the region and global environment."[55] Mathews also expressed suspicion about Japan's intentions: "This [intention to use accumulating plutonium] makes so little economic sense that Tokyo's continuing non-nuclear status is in doubt."[56] More recently, Manning suggested that Japan's plutonium programs, combined with other technological capabilities such as laser enrichment and the H-2 rocket, are sources of concern to its neighbors.[57] As discussed above, Japan's Asian neighbors have become uneasy about Japan's plutonium programs. China, for example, warns that Japan will accumulate plutonium stockpiles that could be used for making nuclear weapons, and views the plutonium issue in the context of Japan's overall technological capability.[58]

Japan's non-nuclear policy, symbolized by its peace constitution, three non-nuclear principles and strong public

[54]Although it was originally reported as MUF, thus questioning the credibility of the safeguards system, 70 kg was revealed as "hold up" (deposited inside the equipment during operation) which is considered to be fully accounted for. However, Japan agreed to reduce the amount to 15 kg. See, "Controversy over 'Hold up' of 70 kg of plutonium inside PNCs' PFPF," Atoms in Japan, May 1994, pp. 19-20, and "STA and IAEA agree to reduce plutonium held up at PNC's facility," June 1994, pp. 19-20. See also "Japanese Nuclear Material Under Full Safeguards," Press release, IAEA, Vienna, Austria, May 25, 1994.

[55]Harrison, S., op. cit.

[56]Mathews, J., "Plutonium on the Loose," The Washington Post, November 28, 1993.

[57]Manning, R., "Rethinking Japan's Plutonium Policy: Key to Global Non-Proliferation and Northeast Asian Security," The Journal of East Asian Affairs, Vol. IX, No. 1, Winter/Spring 1995, pp. 114-131.

[58]Report of the U.S.-Japan Study Group on Arms Control and Non-Proliferation After the Cold War, op. cit. 1995, p. 48.

anti-nuclear sentiment, have been understood as a foundation of Japan's security policy.[59] However, occasional statements made by Japanese high-ranking officials have at times raised suspicions that Japan may still have an interest in acquiring nuclear weapons. These statements have attracted more attention recently, in particular in the context of the situation on the Korean peninsula.[60] One of the more significant events was the reluctance of Prime Minister Kiichi Miyazawa to endorse the "indefinite extension of NPT beyond 1995."[61] When newly elected Prime Minister Hosokawa supported indefinite extension, the editorial column of the nationwide newspaper Asahi Shimbun said: "..the indefinite extension of [NPT] could lead to making the privileged status of nuclear powers an established matter... As a national sentiment, opposition to the indefinite extension based on this spirit is probably more predominant."[62] These developments were perceived by some as a sign that Japan intends to keep open the nuclear weapons option.[63]

Furthermore, the Asahi Shimbun recently reported the existence of a secret Government report prepared 25 years ago dealing with a nuclear weapons option for Japan.[64] The report, written between 1968 and 1970, recommended that Japan not acquire nuclear weapons and was used to support the argument to join the NPT and establish the three non-nuclear principles later adopted by the Diet. However, the existence of the report itself raised concern that the Japanese Government had not been totally forthcoming in claiming that it had never considered development of nuclear weapons. More importantly, the report cited a lack of technological capabilities as one of the reasons for its recommendation against weapons development. The capabilities cited by the report that were lacking included uranium enrichment and reprocessing, both of which have now been acquired through Japan's civilian nuclear programs. Therefore, the Asahi said, the technological barriers that once existed no longer exist.

The Japanese Government has both confirmed and denied that Japan has the capability to produce nuclear weapons. Most recently, the Foreign Ministry issued a statement to the effect that "..mere possession of high-level nuclear technology does not signify the capability of producing nuclear weapons. Japan does not have any expertise or experience in producing nuclear weapons. This means that Japan does not have the capability to produce them." The statement was issued in order to offset Prime Minister Hata's comment: "it is certainly the case that Japan has the capability to possess nuclear weapons, but has not made them."[65] These inconsistent statements have not assuaged foreign concern.

Despite those suspicions, there has been no evidence to support the argument that current plutonium programs have been motivated by an intention to enhance Japan's capability to acquire nuclear weapons. The Tokai reprocessing plant can produce roughly 450 kg of fissile plutonium per year, which could in principle be used

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[59]For example, see Katzenstein, P., Okawara, N., "Japan's National Security: Structures, Norms, and Policy Responses in a Changing World," Cornell University East Asia Program, 1993.

[60]For example, former Foreign Minster Kabun Muto was quoted by the Los Angeles Times on July 28, 1993, saying "if North Korea develops nuclear weapons and that becomes a threat to Japan, first there is the nuclear umbrella of the United States upon which we rely on.. But if it comes down to a crunch, possessing the will that 'we can do it' is important." Quoted in Harrison, S., "Japan's nuclear stance," letter to the editor, November 23, 1993.

[61]Imai, R., op. cit., p. 128.

[62]"Go slowly on extension of nonproliferation treaty," editorial, August 30, 1993, (translated in Asahi Evening News).

[63]Harrison, S., op. cit.

[64]"Kakubuso Kano Daga Motenu (Nuclear Weapon is possible to acquire, but politically not possible)", The Asahi Shimbun, November 13, 1994.

[65]Quoted in Sanger, D., "In Face-Saving Turn, Japan Denies Nuclear Know-How," The New York Times, June 22, 1994.

to produce 40-50 nuclear bombs per year. Although the facility is fully safeguarded and the plutonium recovered is not weapons-grade, technical know-how and experience to produce enough plutonium for nuclear weapons could be gained through the existing plant. Thus, a very expensive commercial facility is not necessary to maintain a technological option. In fact, nuclear weapons programs in nuclear weapons states did not use commercial programs to build the capability for nuclear weapons. There is also concern about the planned RETF (Recycling Equipment Test Facility) which will reprocess spent fuels from FBRs that can contain weapons-grade plutonium. But, since the difference between weapons-grade and reactor-grade plutonium is not significant, building an operating RETF will not add much to existing know-how.

Finally, there is concern that building a large plutonium stockpile through a legitimate commercial scale program may be a useful step to increase an eventual weapons capability. This argument makes little sense since Japan could accumulate a substantial amount of plutonium with existing plants if it were able to do so without breaching any international obligations. Furthermore, Japan's willingness to increase the transparency of its plutonium programs can be considered as evidence of lack of intent to enhance a nuclear weapons capability by that means. In sum, there is no evidence that plutonium programs were related to a nuclear weapons intention. In any case, there is no logical need for a commercial scale reprocessing plant or breeder programs for the purpose of improving expertise in nuclear weapons manufacturing.

E. Plutonium Shipments

The physical protection of shipments of plutonium and vitrified waste from Europe back to Japan was the source of much of the recent public criticism of the Japanese plutonium program. The physical risks cannot be completely eliminated, but Japan's attention to the dangers appear to have minimized them. The publicity was due in part to the actions of nuclear power opponents, but the general lack of adequate rationale for the overall program contributed to the adverse attention.

When the reprocessing contracts with BNFL and COGEMA were signed in the 1970s, the political difficulties encountered in the transportation of plutonium were not envisioned, or were so far in the future that decision makers were not concerned. International attention to the plutonium shipments was low during the 1970s when shipments were fairly routine. A total of 13 shipments were conducted between 1970 and 1979; only three were air shipments, the rest were by sea.[66]

One reason that these shipments did not raise significant concern was the small quantity of plutonium per shipment. Between 1970 and 1979 the shipments varied from 25 kg to 100 kg and were from Britain to Japan. In 1981, 190 kg were carried in one shipment.[67] And in 1984, a similar amount (253 kg in total) of plutonium was shipped from France, but it became a larger political issue.[68] Until 1984 the plutonium was not of U.S. origin (spent fuel from the Gas Cooled Reactor supplied from the U.K.), which perhaps contributed to the lack of attention.

The 1992 shipment was the first conducted under the new 1988 Agreement between the U.S. and Japan. The quantity of plutonium shipped was large: 1.7 tons of plutonium in total. The shipment was expected to be the first of a series of around 30 planned over the coming decade. Since the shipment would be an important precedent, negotiations between Japan and the U.S. took more than two years to conclude. The U.S. approved the plan in August 1992 and the shipment was successfully conducted from November 1992 through January 1993.

Overall, the safety measures taken by Japan, including the escort ship operated by the Maritime Safety Agency, were considered adequate by foreign governments. In June 1993, the General Accounting Office (GAO) issued a report on Japan's plutonium shipment responding to a request from Senator John Glenn. The report

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[66]Berkhout, F., Suzuki, T., and Walker, W., "Surplus Plutonium In Japan and Europe: An Avoidable Predicament," Massachusetts Institute of Technology (MIT) Japan Program, MITJP 90-10, September 1990.

[67]ibid. p. 19.

[68]See the detailed description in Chapter I.

concluded: "U.S. officials were satisfied that all the precautions had been taken to ensure a secure and safe voyage."[69] Furthermore, in September 1993, the U.S. Department of Energy published a study on the safety of plutonium shipment by sea required by Section 2904 of the Energy Policy Act of 1992. The report confirmed that the packages and casks used in the shipment were adequate, and that the possible risks in the case of accident for both the environment and the public were very low.[70]

Future shipments will likely be in the form of fabricated MOX fuel assemblies rather than powders as in the 1992 shipment. And utility companies, instead of Japanese government agencies such as the STA and PNC, will be in charge.[71] It has been reported that Japanese utilities and MITI once questioned whether physical protection measures could be relaxed since MOX fuel is more resistant to terrorism than plutonium oxide powder.[72] From a technical point of view, MOX fuel provides an additional barrier to possible diversion. But international regulation does not distinguish such differences, since MOX fuel is still considered to be "easily accessible" by possible terrorists or sub-national groups. Both MOX fuel and powder are listed as "Category I" under the IAEA Convention, which requires the highest standard of physical protection. It is thus unlikely that the U.S. would approve the relaxation of security measures for MOX fuel transportation.

Under the 1988 US-Japan agreement, Japan received programmatic approval for overall plutonium programs, i.e. Japan does not need to provide "demonstration of need" for each individual shipment. Annex I of the implementing agreement lists all the facilities approved for plutonium use. As long as plutonium is to be used in the listed facilities, Japan does not have to demonstrate further need. The list, however, does not include possible future facilities such as a MOX fabrication plant in Europe with which Japan plans to contract for MOX fuel. Japan will have to add these facilities to the list and get approval from the U.S. for providing plutonium for them. President Clinton's non-proliferation policy of September 1993 stated that the U.S. will maintain its "existing commitment" to plutonium programs in Europe and Japan, but it is not clear whether adding new facilities to Annex I will be considered within the "existing commitment" as it stands.

At the same time, French export law requires Japan to provide "demonstration of need" in order to issue an export license. Walker described what happened between France and Japan on this issue:

> "...an argument broke out between the French and Japanese governments over the latter's reluctance to provide the former with a 'demonstration of need' for the plutonium that it was seeking to transfer.....The Japanese government misjudged the situation because it assumed that France would regard the programmatic approval provided under the US-Japan Agreement as a sufficient qualification. The French requirement turned out to be much tougher than the American requirement."[73]

Therefore, it is possible that "demonstration of need" could become a political issue for future shipments. In particular, the outcome of the current US-Euratom negotiations has important implications for future Japanese plutonium shipments. If shipments are not carried out as planned, because of stronger opposition for example, more plutonium could accumulate in Europe, with growing political controversy.

Information Disclosure

The Convention of Physical Protection as well as the IAEA guidelines (IAEA INFCIRC/225/Rev.1, 1977) set

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[69] U.S. Congress, General Accounting Office, "Nuclear Proliferation: Japan's Shipment of Plutonium Raises Concerns About Reprocessing," GAO/RCED-93-154, June 1993.

[70] U.S. Department of Energy, "Safety of Shipments of Plutonium by Sea," September 1993, DOE/EM-0103.

[71] Depending on the Tokai reprocessing plant operation as well as Monju's operational performance, PNC may need additional shipment of PuO_2 powder.

[72] Walker, W., "The U.S.-Euratom Disagreement," Discussion Paper #55, The Royal Institute of International Affairs, March 1995, p. 30.

[73] ibid., p. 11.

general rules that limit information disclosure about the transportation of nuclear materials.[74,75] The resulting secrecy surrounding the 1992 shipment added to the level of concern about the shipment routes. Based on the lessons learned from that shipment, the Japanese Government has taken measures to disclose more information about future shipments. However, in the case of the recent (1995) high level waste shipment, Britain and France, who owned the transportation ship (Pacific Pintail), prevented information disclosure apparently for public relations reasons.[76] Since information disclosure principles are matters for national decision, Japan has no control over French and British policy. A policy consensus among nations regarding information disclosure would clearly help to provide more confidence for concerned parties.

Avoiding and Minimizing Risks

Finally, the frequency of shipments has been a target of criticism. Although commercial contracts are not disclosed, it is believed that Japan has a contractual requirement to ship plutonium back from Europe in a reasonably short period of time once it is separated from spent fuel.

It is estimated that the total plutonium that must return to Japan under existing contracts is about 30 tons (fissile). Since americium buildup in separated plutonium is a major safety concern in fabrication, the storage time of plutonium powder before fabrication must be minimized. MOX fuel storage, on the other hand, is flexible. Thus, by sending plutonium to a fuel fabricator in Europe, the pressure for early shipment to Japan could be reduced, although the total number of shipments may not be decreased. Larger containers or ships can also be used, thus reducing the number of shipments, but this could increase the physical protection risk per shipment.

The easiest way to reduce the frequency of shipments is to delay or scale down the reprocessing contract with the U.K. and France. Japan would have to negotiate to change the contract, and would probably incur a penalty, as well as the costs of additional storage for spent fuel in Japan. There are several reported examples of European utilities successfully negotiating changes in their reprocessing contracts. For example, German utilities now have decided to cancel contracts beyond the base contract which will expire in 2002, as they concluded spent fuel storage would be more economical than reprocessing even with contract cancellation penalties. Scottish Nuclear Power also conducted an economic analysis of its reprocessing contract with BNFL. Although the situation is different from that of Japan, it concluded that while continuing the current reprocessing contract, it would be less expensive to delay reprocessing and pay an extra charge for longer spent fuel storage than to proceed with the original early reprocessing.[77] A similar study could be conducted for Japan, for if Japan could slow the schedule and reduce the scale of reprocessing contracts, that would reduce proliferation and physical security concerns associated with plutonium shipments.

Minimizing the number of shipments and providing adequate information about them would help to reduce reaction to future shipments. However, in the context of the questions about the reprocessing program itself, some criticism is bound to continue. Obviously, the attention to shipments will decline when they are no longer necessary because of the reprocessing capability within Japan. However, reduced criticism on this score will be more than offset by the overall concern about the plutonium program as outlined above.

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[74]Article 6 of the Convention says: "1. States Parties shall take appropriate measures consistent with their national law to protect the confidentiality of any information which they receive in confidence by virtue of the provisions of this Convention..."

[75]INFCIRC/225/Rev. 1, #6.1.3 says: "Transit operations should not be advertised if this could lead to a decrease in the degree of physical protection."

[76]Nucleonics Week, March 16, 1995, p. 15.

[77]Earlier, Scottish Nuclear Power concluded that building new spent fuel storage is more economical than keeping the reprocessing contract. The details of this updated analysis have not been disclosed.

III. INTERNATIONAL PERCEPTIONS OF PROGRAM RATIONALES

The various arguments presented by Japan in defense of its plutonium programs are not seen as sufficiently convincing by parties in other countries to explain the extent and expense of the commitments to them. These official rationales include arguments that the plutonium programs improve energy security, provide economic benefits, and offer environmental advantages.

A. Energy Security

The most common argument presented by Japan for closing the fuel cycle is that uranium resources on a global basis will eventually be limited, so that the energy content in uranium should be used to the maximum extent possible. According to this argument, commitments to nuclear power in other countries are likely to increase and create competition for scarce supplies. Japan would actually assist others by making it easier to meet global demand for uranium. Moreover, Japan does not have significant indigenous energy resources, either of fossil fuel or uranium, so that the buildup of a reliable indigenous source is seen to be essential to improve the nation's energy security against the danger of supply interruption. Each element of this rationale is treated below.

Long Term Fuel Supply

Official Japanese government documents cite the reserve/consumption ratio of uranium as about 75 years.[1] This would seem to suggest that uranium resources are as limited as fossil fuels such as oil or natural gas.[2] Japan stresses the importance of long-term global energy considerations, arguing that it is Japan's responsibility to promote plutonium use in order to save a precious resource for the global community. From this perspective, Japan is "one of the few countries to be able to perform R&D with the long-range point of view."[3]

The latest JAEC White Paper, published in October 1994, stresses the long term global energy picture and the role of plutonium in meeting growing nuclear energy needs. The White Paper, referring to a study done by the Institute of Energy Economics(IEE), insists that "a nuclear fuel cycle must be established as early as possible to avoid a future energy crisis."[4] The IEE study, which was commissioned by the JAEC, projects various future global energy scenarios up to the year 2100 in which there are tight constraints on CO_2 emissions.[5] In that case the IEE predicted that a serious energy supply shortage could occur by the mid-21st century if full-fledged nuclear fuel recycling in breeder reactors is held back until assured uranium reserves are near exhaustion. The basic assumptions and conclusions of the study were: (1) world population will reach 8.3 billion by the year 2100, the equivalent of a UN "low growth" scenario; and (2) total world uranium resources are 17 million tons, a figure taken from a 1993 OECD/NEA study.[6] The IEE study then considered two scenarios. In the "base case" scenario, with no restriction on CO_2 emission, coal resources are large enough to match the increased

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[1]Typically, the reserve/production ratio is used. But, since current uranium production is much smaller than consumption, the Japanese government uses reserve/consumption ratios. Please see Table 3-1.

[2]See, for example, Ministry of Foreign Affairs, "Striving for Long-term Energy Security: Japan's Policy on the Use of Plutonium," February 1995, and Y. Moriguchi, "Japan's Perspective on Peaceful Usage of Plutonium," Genshiryoku Kogyo, January 1994, pp. 10-15, translated in "Current Status and Issues of Technology for Plutonium Use," Science and Technology, JPRS Report, 15 September 1994, pp. 1-6.

[3]ibid, p. 2.

[4]"Atomic Energy White Paper Unveils Conditions of Japan's Plutonium Inventory," Atoms in Japan, November 1994, pp. 4-7.

[5]The IEE, "Genshiryoku Hatsuden no Shourai Tenbo Ni Kansuru Chosa (Study on Long Term Prospect of Nuclear Power)," Summary, Enerugi Keizai (Energy Economics), Vol. 21, No. 1, January 1995.

[6]Nuclear Energy Agency, OECD, "Uranium Resources, Production and Demand," 1993.

Table 3-1
World Uranium Reserve/Production Ratio*

Year	Reserve	Production	R/P	Real Price**	Nuclear Growth Projected
	(million MTU)		(Years)	($/lbU3O8)	(%/year)
1967	1.06	0.018	59	21.9	28.8%['70-'80]
1973	1.55	0.020	77	13.8	24.2%['70-'90]
1981	2.29	0.043	53	25.1	9.2%['80-2000]
1993	2.20	0.034	65	8.5	~2-3%['95-2010]
[1993 total	4.33	0.057	76]		

* excluding former Soviet Union and Eastern Europe [1993 total]
** Nuexco exchange price, deflated to 1993 price

Source: Compiled from data by OECD/NEA, IAEA, and Neff (1984).

energy demand. However, under a "CO_2 reduction case" (CO_2 emissions held to current levels), coal consumption is limited and uranium consumption is increased. Under this scenario, Japan's nuclear power capacity would grow to 305 GWe by 2100. If plutonium recycling is limited until uranium reserves become scarce and expensive in the latter half of the next century, a serious global energy shortage could occur at about the middle of the 21st century.[7]

Similar studies have been done outside Japan. According to a 1994 report by Stanford University[8], if the present 20% nuclear power share of electricity generation is maintained, there would be 2,500 nuclear plants worldwide in 2060 compared to 424 in 1994. And if the nuclear energy contribution were to rise to 40%, for example to keep CO_2 emissions to no more than twice what they are now, there would have to be more than 4,000 nuclear plants. Perhaps more importantly, half or more of the plants, the study says, would have to be in Asia, several hundred in China alone.[9] Therefore, the study concludes that the "continued use of nuclear power will require reprocessing the spent fuel to obtain plutonium, unless massive new (economic) uranium resources are identified."[10] A study done at MIT also suggests that a serious nuclear response to global warming would require, sooner or later, heavy use of breeder reactors.[11]

These studies in Japan and abroad are based on assumptions of the growth of overall energy consumption, the unavailability of alternative energy sources, and the maintenance or growth of nuclear power's share in total electricity generation. But the most fundamental assumption is that economically competitive uranium resources will eventually be depleted. If this basic assumption is valid, then it could be argued that plutonium use will be all but inescapable. Most resource economists and geologists working on uranium, however, would challenge the premises of this argument about the scarcity of natural uranium under various scenarios of nuclear power use. The need for early commitment to reprocessing in order to obtain plutonium because of limited uranium supplies is thus seen as questionable.

First, nuclear power has not grown at projected rates. During the 1960s and early 1970s, when the rapid expansion of nuclear capacity was expected, and known uranium reserves were inadequate to meet the predicted demand, it was reasonable to seek to commercialize FBR and plutonium use as soon as possible. But nuclear reactor growth has been much lower than expected. For example, in 1975, the U.S. Energy Research Development Administration estimated the total nuclear capacity in the U.S. would grow to 3,700 GWe by 2025.[12] The current U.S. total capacity is around 100 GWe and is essentially flat and may decline in the future. The International Nuclear Fuel Cycle Evaluation (INFCE) predicted that the worldwide nuclear capacity would be 850 GWe in 2000 even in their low growth estimate.[13] The current worldwide nuclear capacity is less than

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[7]The IEE, op. cit., 1995.

[8]May, M. and Avedon, R.E., "The Future Role of Civilian Plutonium," Summary Report of a Workshop Held at Stanford University, March 29-30, 1994, Center for International Security and Arms Control, Stanford University.

[9]ibid., p. 10.

[10]ibid., p. 11.

[11]Golay, M. "What role should nuclear power play and what would life be without it?" Keynote paper for the Second MIT International Conference on the Next Generation of Nuclear Power Technology, 25-26 October, 1993.

[12]Feiveson, H.A., von Hippel, F. and Williams, R.H., "Fission Power: An Evolutionary Strategy," Science, Volume 203, 1979, pp. 330-337.

[13]"International Nuclear Fuel Cycle Evaluation," Working Group 9, Summary Volume, IAEA, 1980, p. 5.

350 GWe and is now expected to grow to no more than 400 Gwe by 2000.[14]

Second, the economics of natural resources and the past history of resource availability, suggest that uranium reserves would be found to be larger if demand were to increase and prices rise. The creation of reserves requires investment that can be recovered only with production. There is not much incentive for industry to look for additional reserves when the demand is weak and the price is low. "Resource" estimates, which are beyond "reserve" estimates, are typically based on geological surveys. Both resource and reserve estimates are conditioned by the current level of technology and knowledge about resource exploration and recovery. In general, as markets expand or as prices rise, new reserves are discovered and old deposits are more efficiently mined since there are increased incentives. Moreover, knowledge and technologies for both exploration and recovery are also likely to improve over time. Thomas Neff notes that "... most of the empirical evidence (on exhaustion) is at best non-supportive and more often contradictory."[15] Since the supply of uranium has expanded and will continue to expand, the price of natural uranium remains very low (less than \$10/lb U_3O_8) at present and there are no signs of an increase in the foreseeable future. This situation is not unique to uranium. The historic concern about a limited supply of fossil fuels has not materialized. Table 3-2 shows that both natural gas and oil reserves have expanded to meet expanded demand (production) in the last four decades. As a result, reserve/production (R/P) ratios for oil and natural gas have *increased* from the 1970s to the present, from 32 years to 46 years for oil and from 39 years to 55 years for natural gas.

Third, if shortfalls were to materialize, there are other, less expensive and less controversial, paths to extending and securing uranium resources. These would include greater investment in developing new uranium supplies in any of many promising regions, diversifying supply sources, stockpiling to buffer against supply interruption, and improving fuel efficiency by moving to higher burn-up LWRs. In fact, there have been substantial new discoveries of uranium reserves during the 1970s. As Table 3-1 indicates, the so-called "Reasonably Assured Reserves and Resources" estimated by OECD/NEA, more than doubled from 1 million tons of uranium in 1967 to 2.3 million tons of uranium (at a price range of less than \$130/kg U, i.e. ~\$50/lb U_3O_8) in 1981.[16] It should be noted that some of those newly discovered reserves, mostly in Canada and Australia, were much "richer" in grade than earlier reserves. The most significant new discovery was Roxby Downs Station in South Australia. This deposit alone (about 1 million tons with 0.07 percent concentration) is equal to the world total of reasonably assured reserves and resources of only 7 years ago.[17]

Short Term Supply Interruption

Reassuring predictions about the availability of resources in the face of possible resource shocks may not be fully satisfying for a nation with limited indigenous resources. This is especially so for Japan for whom energy security concerns have a long history and a symbolic significance that may not be as strong in other nations. One of the underlying rationales for the plutonium program has therefore been to maintain a technology option in case uranium resources are not as plentiful as forecast, or in the event of the need to move more energetically to nuclear power if there are increased environmental threats from the consumption of fossil fuels.

One concern is of a cutoff of supply of uranium to consumer countries as the oil cartel did with oil in the 1970s. Only four countries, Australia, Canada, the United States, and South Africa, share 75% of total reasonably assured reserves. In addition, supplier governments have either direct ownership in production capacity and/or

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[14]Japan Atomic Industrial Forum, "Nuclear Power Plants In the World," Edition 12, As of December 31, 1994.

[15]Neff, T., "Are Energy Resources Inexhaustible?", International Resources Programme, The London School of Economics and Political Science, November 11, 1985, p. 8.

[16]Neff, T., "The International Uranium Market," Ballinger, Cambridge, MA, 1984.

[17]Neff, T, "Are Energy Resources..." op. cit., p. 10. Neff argues that massive new discoveries of less expensive uranium reserves during the 1970s and early 80s eventually shifted the supply curve downward. This resulted in much lower prices than were originally expected.

Table 3-2
Historical World Reserve/Production Ratio
for Oil and Natural Gas

Year	Oil Reserve (billion bbl)	Production (billion bbl)	R/P (years)	Natural Gas Reserve (Trillion ft^3)	Production (Trillion ft^3)	R/P (years)
1950	76.5	3.8	20.1	n.a.	n.a.	n.a.
1960	290.0	7.7	37.7	n.a.	n.a.	n.a.
1970	530.5	16.7	31.8	1491.3	38.1	39.1
1980	644.9	21.8	29.6	2574.8	58.5	44.0
1990	1002.2	21.7	46.2	3991.2	75.3	53.0
1991	999.1	21.5	46.5	4208.3	76.0	55.4

Source: American Petroleum Institute, "Basic Petroleum Data Book: Petroleum Industry Statistics," Volume XIII, Number 2, May 1993.

strong controls over uranium exports. Thus, a sudden policy change in these countries could result in supply disruption. During the 1970s and even the early 1980s such a concern appeared to be justified. Canada and Australia, especially the former, embargoed the export of uranium to major consumer nations including Japan after the Indian nuclear explosion of 1974.[18] There are also concerns over the adequacy of production capability. A recent forecast by OECD/NEA (1994) shows that annual world uranium requirements (57,000 tons U) already exceed world production (36,000 tons U), and that this gap will widen in 2010 as demand will increase to 75,000 tons U while production capacity may decrease, even with the planned and prospective additional capacity.[19] These gaps of production capacity reflect a glut in the uranium market which would be reversed if uranium demand should increase.

Will commercial plutonium use address concerns over short-term fuel supply cutoffs or shortages? Several factors indicate that a nuclear power system is much more resilient than conventional fossil fuels against a fuel supply interruption or sudden price increase, even without use of plutonium. First, nuclear fuel in a reactor can last at least a year and can be extended by technical means such as coasting down. "Coasting down" refers to the gradual reduction of power output which results in extended fuel life (resource savings). By cutting power output, one may extend the period of operation. Second, it is easier to stockpile uranium fuel than fossil fuels since the energy content of uranium per unit volume is much higher. In fact, France, the U.S. and the U.K. have a policy of stockpiling of uranium equivalent to 2-3 years supply.[20] Third, the cost of uranium is less than 5% of the total cost of nuclear power generation. Thus, tripling uranium prices would result in only a 15% increase in the cost of nuclear generated electricity. Finally, introducing plutonium in the LWR fuel cycle may not improve this inherent resilience. It would have a "diversification" effect on overall supply. But, unless a country has both a reprocessing capacity and a MOX fabrication facility which can be readily expandable to meet additional demand, the value of plutonium for use as a buffer against uranium supply interruption is very limited.

Near-term Plutonium Use and Long-Term Breeder Development

Japanese commercial plutonium programs aim at reducing near-term energy dependency by substituting plutonium for some imported uranium and at reducing long-term energy dependency through the introduction of fast breeder reactors. Although Japan has extremely limited domestic uranium resources, nuclear power is categorized by the Japanese government as a "semi-domestic" energy source because a nuclear power system can be "self-sufficient" if a plutonium breeder system is established. Under current conditions of uranium and plutonium glut, Professor Akira Oyama, former Vice Chairman of JAEC, clearly stated that Japan's goal has been shifting from maximizing plutonium production to maintaining the breeder option:

> We must admit that worldwide efforts for fast reactor development are diminishing.... Should we, then, give up the fast reactor option? I don't think it is wise to give it up.... it is not easy to sustain such long-term R&D efforts.... I think, moreover it is very understandable that some fast reactors in the world are planned to operate as burners of plutonium or other actinides. Our intention at present and in near future is to maintain this important option for the future generation, and not to increase the quantity of plutonium in the world.[21]

This long term goal of moving toward FBRs operates in parallel with a short term goal of reducing dependency on imported uranium. How much can near-term uranium consumption be reduced through plutonium separation and MOX burning in LWRs? Will near-term consumption of plutonium facilitate or block longer term plans for reducing energy dependency through the introduction of breeder reactors?

Near-term plutonium use offers modest uranium savings. Under the current long-term program, the cumulative plutonium supply up to 2010 will be about 80 tons. It is assumed that 20 tons will be used in MOX fuel by the

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[18]Neff, T., op. cit., 1984, p. 160.

[19]OECD/NEA, op. cit. pp. 68-69.

[20]ibid.

[21]Oyama, A., "Nuclear Energy in Japan: Past, Present and Future," presented at the annual Winter meeting of American Nuclear Society/European Nuclear Society, Chicago, November 16-19, 1992.

year 2000, and the rest (60 tons) will be used by 2010. Assuming the conversion ratio of plutonium to natural uranium as 140 (i.e. 1 ton of plutonium equals 140 tons of natural uranium),[22] cumulative savings of uranium consumption by 2000 will be only about 7%, and less than 10% up to 2010. Even if we assume that plutonium supply will increase rapidly after 2020 by building another 800 tons/y reprocessing plant, cumulative savings could not go beyond 10%, assuming nuclear power capacity will grow to 100 GWe by 2030 (Table 3-3).

Is a commitment to a large scale commercial plutonium program at this time needed to maintain the viability of a long-term breeder option? It is argued that to achieve this objective, Japan must "establish a comprehensive technology system" and "implement nuclear fuel recycling on a large-enough scale."[23] One reason for constructing a commercial-scale reprocessing plant is to allow Japan to accumulate experience in nuclear fuel recycling. Further, it is argued, because of long technological lead times, Japan needs to establish a large-scale commercial plutonium program now.[24] International responses to these arguments center on two points.

One problem with plutonium use centers on the inconsistency between Japan's current fuel plans for reprocessing and MOX burning in LWRs, and Japan's long term declaratory goal of relying on FBRs for commercial power generation. Building a substantial FBR system in a limited time period would require large amounts of plutonium for start-up cores.[25] Spent fuel reprocessing and MOX burning in LWRs <u>now</u> would reduce plutonium available for FBR cores <u>later</u>. By contrast, long-term spent fuel storage for possible future reprocessing would be more consistent with Japan's declaratory policy of moving toward FBRs as a significant commercial power source.[26] Paradoxically, current plans for commercialization of plutonium may prolong rather than shorten the period of Japanese energy dependency.

Another problem centers on the timing and nature of commercialization. Is acquisition and development of technology maximized through use of MOX in LWRs and the construction of a large reprocessing plant based

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[22]Because of the negative effects of Pu-242, the energy equivalent value of fissile plutonium to U_{235} would be at most 85% of the theoretical maximum. The value of 80% is used by the U.S. Nuclear Regulatory Commission. Thus, the savings would be smaller. We estimate that all the savings are due to MOX recycling since breeder contribution will still be very small by 2030.

[23]JAEC, "Long Term Program for Research, Development and Utilization of Atomic Energy," June 24, 1994.

[24]Ito, K, and Hayamizu, Y., "Plutonium Usage for Advanced Reactors," Genshiryoku Kogyo, January 1994, pp. 16-23, translated in Science & Technology Japan, JPRS-JST-94-029, 15 September 1994.

[25]This plutonium supply issue has been suggested by a number of nuclear energy experts in the U.S. and in Japan. See for example, Wolfe, B., Lambert R.W., and Melde, G.F., "Will there be enough plutonium?", Nuclear News, April 1977, pp. 72-78. For Japan, see Furuhashi, A., "Dependence of Long-Term Fuel Demands on Reactor Type (1) & (2): Effects of Plutonium Recycling and Plutonium Producing Reactors," (in Japanese), Nihon Genshiryoku Gakkai-shi (Journal for the Japan Atomic Energy Society), Vol. 16, No. 11, 1974, pp. 582-590 and No. 12, 1974, pp. 632-639. Yamaji, K., "Reactor-type choice and nuclear fuel utilization efficiency," (in Japanese), Nuclear Engineering (Genshiryoku Kogyo), vol. 24, No. 8, 1978, pp. 31-36. Meanwhile, the FBR with enriched uranium (20%) start-up will reduce plutonium demand, but it requires a large uranium supply (2242 tons/GWe for the initial core, more than 6 times that of a LWR). In addition, there is a penalty in breeding ratios (0.97). Therefore, uranium requirements will increase substantially in the short term, and savings will appear only after a long time. See Suzuki, T., "Long term logistic analysis of FBR introduction strategy: avoiding both uranium and plutonium shortage," presented at International Conference on Evaluation of Emerging Nuclear Fuel Cycle Systems, September 11-14, 1995, Versailles, France (forthcoming).

[26]See Furuhashi, op.cit. He concluded that plutonium recycling in LWRs would reduce immediate uranium demand at the expense of long-term self-sufficiency.

Table 3-3
Uranium Savings by Plutonium Use in Japan
(1993 to 2030)

Year	Nuclear Capacity (GWe)	Cumulative Uranium Req. (from 1993) (tons U)	Savings by Pu Use (tons U)	Savings (%)
2000	42	41,207	2,800	6.8%
2010	56	116,128	11,200	9.6%
2020	72	213,984	18,200	8.5%
2030	100	345,478	32,200	9.3%

Asssumption:

Pu Supply:
- 1993-2000 20 tons (5 t from Tokai, 15 t from overseas)
- 2000-2010 60 tons (45 t from Rokkasho, 15 t from overseas)
- 2010-2020 5 tons/y (from Rokkasho) 50 tons in total
- 2020-2030 10 tons/y (from two Rokkasho size plants) 100 tons in total

Uranium requirement:

1 GWe APWR, at 70% capacity factor, 0.25% enrichment tail
initial core 333 tons/y, reload 127 tons/y

Source: Estimated from data by JAEC, OECD/NEA.

on purex technology imported from France.[27] In fact, there is often a trade-off between "early commercialization" and a "long-term R&D" strategy. Early commercialization can bring large profits if such new technologies become commercially viable and if demand becomes large enough to pay back the investment. On the other hand, by committing to a technology at an early stage, there is a risk that the technology may become obsolete, or the demand never large enough to justify the investment.[28] If there is no apparent need for early commercialization, a more focused long-term R&D program can lead to innovative technologies that will better serve the overall objective. A similar debate over commercialization of technologies took place in the U.S. in the 1970s over the controversial Clinch River Breeder Reactor (CRBR) project and other new technologies, such as the supersonic transport (SST) project. The CRBR project was eventually canceled, and even the proponents of FBR later said that it was better for FBR technology development not to continue CRBR since it used out-of-date technologies. The SST project was also canceled; the judgment of the Congressional Office of Technology Assessment at the time was that "it appears appropriate to carry out a generic R&D program to preserve the supersonic option instead of full commercialization now."[29]

Long-term R&D on advanced reactors and the nuclear fuel cycle, as well as on other alternatives to fossil fuels, would avoid a premature massive commitment to today's technology that would be obsolete if the technological option in fact becomes important sometime in the future. Operating experience would be gained through a commercial program at this time, but with great cost and little technological gain. Importing French technology instead of developing indigenous technology for the Rokkasho plant is not likely to maximize technological development on either a global or national basis.

Furthermore, a massive commitment to plutonium and breeder reactors in commercial programs could paradoxically make Japan increasingly vulnerable to major accidents, terrorism incidents, or policy changes elsewhere over which the nation has no control. In fact, all nuclear power programs are in a sense hostage to the weakest and least well-protected programs in other countries, which is a different form of "dependence."[30] Although technically speaking plutonium can be considered an "indigenous" energy source, in reality plutonium programs cannot be isolated from external influences. The recent concern about the outcome of the U.S.-Euratom agreement is a good example. If there is a lapse in the agreement, Japan's planned contracts with European MOX fabricators may be in jeopardy.[31]

Alternatives to Plutonium Use

Japan's dominant focus on plutonium to achieve an energy security objective raises many questions. There are other, less expensive and less controversial, paths to extending and protecting uranium resources: for example, greater investment in developing new uranium mines in any of many promising regions, diversifying uranium supply sources, stockpiling to buffer against supply interruption, and increasing the fuel discharge burn up. Japan's total energy R&D budget has a heavy emphasis on nuclear power. In FY 1992, 93% of total

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[27]PNC also imported French technology for the Tokai reprocessing plant.

[28]See the argument in Wolfe, B., "The nuclear fuel cycle: Can our nuclear non-proliferation policy be salvaged?", presented at Atomic Industrial Forum Fuel Cycle Conference '86, April 1-4, 1986, and Collinridge, D. "Technology in the Policy Process: Controlling Nuclear Power, "St. Martin's Press, New York, 1983, p. 145.

[29]OTA, "Impact of Advanced Air Transport Technology," April 1980. In the report, the OTA defined "generic R&D" as "the process of verifying and validating technologies leading to a state of 'technological readiness' for development of a specific product."

[30]See the more detailed argument in Skolnikoff, E.B., The Elusive Transformation: Science, Technology and the Evolution of International Politics, Princeton University Press, Princeton, New Jersey, 1993, p. 155.

[31]The 1988 US-Japan agreement's programmatic approvals are limited to the list of facilities in Annex 1 of the implementing agreement. MOX fabrication facilities in Europe are not listed; therefore it is uncertain if the US-Euratom agreement expires that the U.S. government would agree to add those facilities to the Annex. See the detailed argument in Walker, W., "The U.S.-Euratom Disagreement," op. cit., 1995.

government spending on energy R&D (¥392 billion) went to nuclear power (¥365 billion)[32]. Within the nuclear budget, the share devoted to plutonium-related technologies is by far the highest. For the FY 1993 government R&D budget, the total plutonium-related budget (FBR, ATR, reprocessing and MOX fuel) was ¥120.6 billion, which was 43% of the entire nuclear R&D budget (¥283.7 billion) (Table 3-4, Figure 3-1). Nuclear safety was the next highest, but other fuel cycle R&D allocations including enrichment exploration were only ¥10.4 billion, a mere 4% of the total nuclear R&D budget.

Such a dominant focus at present on nuclear power and especially on plutonium and recycling, with relatively minor investment in other ways of extending uranium resources or developing energy supply options other than nuclear power, contributes to the skepticism encountered abroad as to the validity of this rationale for the program. There are examples of other programs in Japan, some underway or at least considered, that could receive more attention:

(i) Uranium fuel assurance: As Japan has acknowledged, the light water reactor will remain the main reactor type for Japan well into the next century. And even if FBRs are introduced as currently planned, Japan's uranium dependence will likely continue for at least 50-60 years. It is thus sensible to invest in assuring the supply of uranium fuel. Direct investment in uranium mines, new exploration efforts in promising areas, stockpiling of low price uranium ore and/or enriched uranium are all potentially useful measures. Japan's uranium exploration budget (non-domestic), though a small percentage of the overall nuclear budget, is currently the second largest nationally ($15.8 million) next to that of France ($20.3 million). This effort is substantial compared to other countries, but not necessarily commensurate with the need. Governmental exploration has not yet yielded commercially viable uranium mining after twenty years of investment.[33]

(ii) Fuel efficiency improvement: Increasing the burn-up rate of LWR fuel could improve uranium utilization efficiency significantly. For example, by increasing the burn-up rate from 30,000 megawatt days/ton to 50,000 megawatt days/ton, the lifetime (30 year) uranium requirement of a LWR could decrease by about 15% from 4,600 tons to 4,000 tons.[34] Some of the latest Japan's LWR fuels are already achieving 40,000 megawatt days/ton and utilities are now aiming at 50,000 megawatt days/ton for the next generation. In addition, lowering enrichment tails would also help in decreasing uranium demand. For example, by lowering tails from 0.25% to 0.2% for 3.6% U_{235} enrichment (~42,500 megawatt days/ton), the uranium requirement can be reduced about 10%. Savings can be increased to more than 20% by lowering tails to 0.1%.[35]

(iii) Other advanced reactor or fuel cycles: In addition to fast breeder reactors, there are various types of advanced reactors or fuel cycles that can achieve significantly higher fuel efficiency than LWRs. While it is not our purpose to explore such options here, there are several ideas that have been suggested by Japanese experts; such ideas include: (a) once-through, super high burnup reactors that do not require reprocessing or refueling[36], (b) high conversion LWRs using plutonium but able to be operated as a once-through fuel cycle[37], (c) thorium-uranium reactors[38], and (d) once-through LWRs using uranium from sea water.[39]

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[32]Science and Technology Agency, "Indicators of Science and Technology," FY 1994 edition.

[33]General Administration Agency, Bureau of Administration Review, "Genshiryoku Kankei Tokushu Hojin No Genjyo To Kadai (Current Status and Issues of Nuclear-related Special Government Corporations)," December 1989. p. 73.

[34]OECD/NEA, "Nuclear Energy and Its Fuel Cycle," 1987. Based on enrichment tails of 0.25%.

[35]Personal communication with Prof. Harold Feiveson, June 1995.

[36]Akie, H., Muromura, T, Takano, H., and Matuura, S., "A New Fuel Material for Once-Through Weapons Plutonium Burning," Nuclear Technology, August 1994, vol. 107, no. 2, pp. 182-192. Note that this proposal is intended for disposition of plutonium from nuclear weapons.

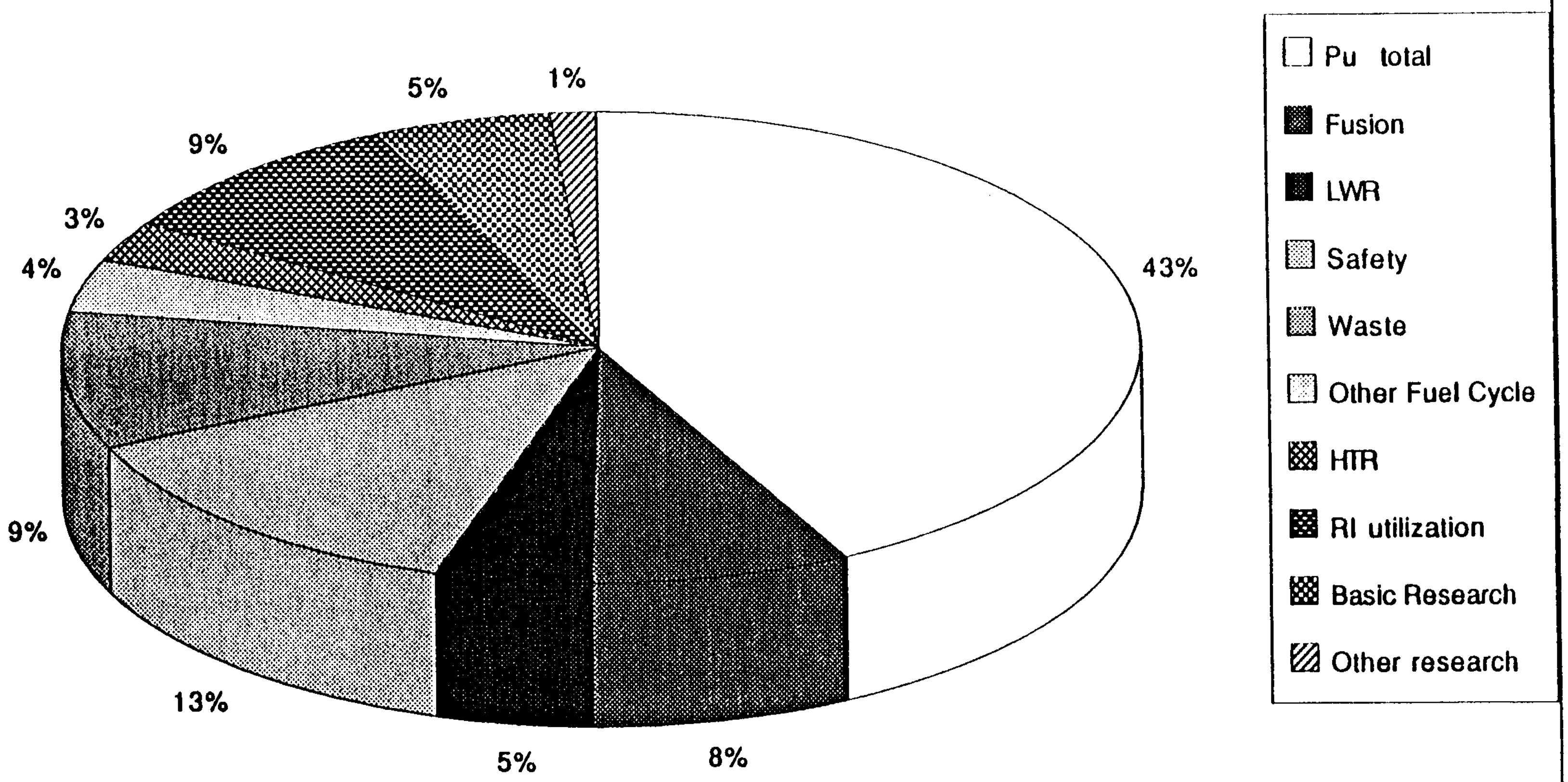
[37]Nagano, K, and Yamaji, K, "Nenryou Saikuru Saiteki-ka Moderu no Kozo To Saiteki-kai no Tokusei (Structure of Nuclear Fuel Cycle Optimization Model and its Characteristics)," (in Japanese), Denryoku Keizai Kenkyu (Electric Power Economics Research), No. 26, 1989, pp. 73-83.

Table 3-4
Japan's Nuclear Budget
(¥ Billion)

	FY1992	%	FY1993	%
FBR+ATR+MOX	93.8	33.6%	94.1	33.2%
Reprocessing	23.1	8.3%	26.5	9.3%
Pu total	116.9	41.9%	120.6	42.5%
Fusion	21.9	7.8%	22.1	7.8%
LWR	13.6	4.9%	14.0	4.9%
Safety	38.3	13.7%	37.7	13.3%
Waste	30.2	10.8%	26.3	9.3%
Other Fuel Cycle	9.7	3.5%	10.4	3.7%
HTR	7.0	2.5%	8.2	2.9%
RI utilization	22.4	8.0%	26	9.2%
Basic Research	15.7	5.6%	14.7	5.2%
Other research	3.5	1.3%	3.7	1.3%
R&D sub total	279.2	100.0%	283.7	100.0%
Public Relations	110.1		126.2	
Others	36.7		41.4	
Total Budget	426.0		451.3	

Source: Science and Technology Agency ed., "Genshiryoku Poketto Bukku (Pocketbook on Atomic Energy)," 1994 edition, Japan Atomic Industry Forum, 1994.

Figure 3-1 Japan's Nuclear R&D Budget (FY 1993)



B. Economic Benefits

A second important cluster of rationales for plutonium programs centers on the long term economic viability of nuclear power with reprocessing. Japanese analysts would now acknowledge that plutonium recycling is likely to be more expensive than the once-through process, but the estimated increment is seen as marginal given the small share of fuel cost in the final cost of electricity. In addition, they argue that plutonium recycling and use of breeders can bring long term price stability in nuclear-generated electricity; thus, it would be a long-term investment in cost stabilization.

Once-Through vs. Recycling

The cost difference between once-through and recycling of nuclear fuel may well be relatively small. Even under conservative assumptions, cost estimates of the recycling option may be higher than the costs of the once-through option. The 1994 study of the Nuclear Energy Agency (NEA) of OECD estimated the long term costs of direct encapsulation and disposal of spent fuel at 140-640 ECU per kg, compared to the cost of reprocessing of spent fuel plus vitrification of high level waste at 630-1300 ECU per kg.[40] The OECD/NEA study concluded that the cost disadvantage of the reprocessing/recycling option is roughly 10% of total fuel cycle cost.[41] It also endorsed the argument that, since the nuclear fuel cycle cost is only a small portion of total power generation cost, such a cost difference would be marginal. Japanese official documents cite these numbers to support their argument.

It is relatively difficult to examine the economic implications of the plutonium fuel cycle in Japan since public literature and data on the subject are limited. However, there are two interesting studies done by Japanese experts on the comparison of once-through and plutonium recycling which might explain how Japan's long-term view affects the economic analysis. The first study done by Deguchi and Kikuchi (1982)[42] concluded: (i) cumulative cost of the reprocessing/recycling option is probably 10% more expensive than once-through if the uranium price remains flat at $40/lb U_3O_8 for the next 40-50 years, (ii) but if uranium prices rise at 1-2%/y for 40-50 years, the reprocessing/recycling option would become less expensive than the once-through option. They assumed the reprocessing cost to be constant at ¥88,000/kgHM (~$400/kgHM(heavy metal)), which is significantly lower than the current price ($1600-$1700/kgHM). The study by Nagano and Yamaji (1989)[43] concluded: plutonium recycling for LWRs will not be competitive at a reprocessing price of ¥170,000/kgHM

[38] Furukawa, K., "Datsu Purutonium E-no Honkaku Togi-O,(Should start serious discussion on non-plutonium future)," Asahi Shimbun, Rondan (Op. Ed.), February 18, 1994.

[39] Hiraoka, T., "Nuclear Electricity Generation Using Seawater Uranium," Atoms in Japan, December 1994, pp. 14-16. The author argues that uranium from sea water can be recovered at ¥34,000/kg of U (~$400/kg U) and that at that rate LWR using such uranium can be competitive (¥9.7- ¥14.6/kWh) with recycling (¥10.4/kWh - ¥15.3/kWh).

[40] For revised estimates, see "NEA study chief says once-through cycle 57% cheaper than reprocessing," Nuclear Fuel, January 2, 1995.

[41] OECD/NEA, "The Economics of The Nuclear Fuel Cycle," September 1994.

[42] Deguchi, M., and Kikuchi, S., "Kakunenryou Saikuru Wo Genmitsu-ni Hyoka Shite Miyo (Let's Examine in detail the Economics of Nuclear Fuel Cycle)," (in Japanese), Genshiryoku Kogyo (Nuclear Engineering), Vol. 28, Nov. 9, 1982, pp. 17-30.

[43] Nagano, K, and Yamaji, K., op. cit., pp. 73-83.

($1300/kgHM)[44] (see Table 3-5). They argue that the timing and scale of plutonium recycling will depend on reprocessing costs. These studies by Japanese experts suggest that plutonium recycling would only be competitive with the once-through cycle in the long-term and under favorable assumptions.

One other important fact to be noted is that the price difference between UO_2 fuel and MOX fuel fabrication is significantly smaller in Japan. According to recent estimates of the OECD/NEA and Rand, MOX fuel fabrication cost is 4-5 times that of UO_2 fuel fabrication cost (see Table 3-5).[45] However, in Japan, since UO_2 fabrication cost is much higher (¥88,000/kgHM, $1000/kgHM) compared to the OECD estimate of $200-275/kgHM, the MOX fuel fabrication cost is only 1.5-1.6 times higher. Since the cost difference of once-through and reprocessing options are largely determined by the differences in fuel fabrication costs (MOX vs. UO_2) and reprocessing costs (minus savings of uranium cost through plutonium use), the reprocessing cost, which is roughly 30% of total fuel cycle cost, is crucial to the relative economics of the nuclear fuel cycle in Japan.

Nuclear vs. Fossil Fuels: The Impact of Rokkasho Commercial Reprocessing

More important than the comparison between once-through and recycling is the impact of the Rokkasho reprocessing plant on the competitiveness of nuclear power. The cost penalty of the commercial reprocessing/recycling program could be large enough to increase the cost of nuclear generated electricity above that generated by fossil fuels. These concerns are reflected in a recent request by the Federation of Electric Power Companies to cancel the DATR project. Nuclear power is still believed to be the least expensive power source in Japan. However, the advantage over fossil fuels, in particular natural gas, is apparently narrowing. Table 3-6 and Figure 3-2 show the relative competitiveness of nuclear power against other fuels estimated by MITI and the Institute of Energy Economics (IEE) respectively. That data shows that in 1992, the cost of nuclear power was virtually equal to that generated by coal and/or natural gas. This could change in the future. Table 3-7 shows the estimated nuclear power economics compared with fossil fuels in 2000 according to IEE.[46] In 1992, nuclear power cost about ¥10.2/kWh, which is expected to come down to ¥9.56/kWh in 2000 mainly due to a reduction in the overall cost of capital. The cost includes decommissioning and reprocessing, but not the cost of final waste disposal. Meanwhile, IEE estimated (base case) that mainly due to increase in capital costs, the costs of electricity from coal and LNG are expected to increase to ¥11.60/kWh and ¥11.55/kWh respectively.[47] Without reprocessing, which is assumed to be around 30% of total fuel cost (~¥0.45/kWh)[48], the nuclear power generation cost will go down to ¥9.11/kWh and thus the price advantages of nuclear power over fossil fuels will be in the range of ¥2.5/kWh without reprocessing.

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[44]The cost is in 1985 prices, translated from dollar prices at an exchange rate of ¥130/$. The original price in dollars was $1300/kgHM.

[45]OECD/NEA, op.cit.; OECD/NEA, Economics of the Nuclear Fuel Cycle, 1994; Chow, B. and Solomon, K., "Limiting the Spread of Weapon-Usable Fissile Materials," National Defense Research Institute, Rand Corp., 1993.

[46]Yuasa, T., "Dengenbetsu Hatsuden Kosuto no Shisan, Bunseki, (An Estimation and an Analysis of Power Generation Costs by Fuel Type)" (in Japanese), Enerugi Keizai (Energy Economics), vol. 15, no. 11, November 1989; Yuasa, T., "Dengenbetsu Hatsuden Kosto no Shorai Doko, (Future Trends of Power Generation Costs by Fuel Type)", (in Japanese), Enerugi Keizai (Energy Economics), vol. 18, no. 11, November 1992, pp. 49-55.

[47]Fuel price of coal and LNG are estimated based on the oil price. Base case scenario assumed constant $20/bbl oil price (1992 price) up to 2000. Capital cost increase is estimated based on utility industry's report to Electric Power Industry Council. Capital cost of nuclear power is estimated to decrease by 7%, while capital costs of coal and LNG are estimated to increase by 6.5% and 26% respectively. These estimates are based on a report submitted by electric utility companies to Electric Utility Industry Council. There is no public data for actual capital costs.

[48]Interview with IEE official, January 1995. This is roughly equivalent to the reprocessing price of $1700/kgHM at ¥85/$.

Table 3- 5 Fuel Cycle Economic Studies in Japan

Assumptions on Reprocessing, MOX fuel, etc.

	UO_2	MOX	MOX/UO_2	Reprocessing
	(¥1,000/kgHM)	(¥1,000/kgHM)		(¥1,000/kgHM)
JAEC (1981)	n.a.	146.0	n.a.	n.a.
Deguchi (1982)	87.2	130.0	1.49	88.0
Nagano (1989)	80.0	130.0	1.63	170.0
Yuasa (1989)	88.0	n.a.	n.a.	146.4
Yuasa (1992)	88.0	n.a.	n.a.	177.0

	($/kgHM)	($/kgHM)		($/kgHM)
OECD/NEA (1989)	200	800	4.0	500-1000
OECD/NEA (1994)	275	1100	4.0	720
Rand (1993)	200	800-960	4.0-4.8	450-1600

Source: JAEC, ATR Demonstration Evaluation Committee Report. 1981. Deguchi and Kikuchi (1982), Nagano and Yamaji (1989), Yuasa (1989, 1992). OECD/NEA (1989, 1994). Rand (1993).

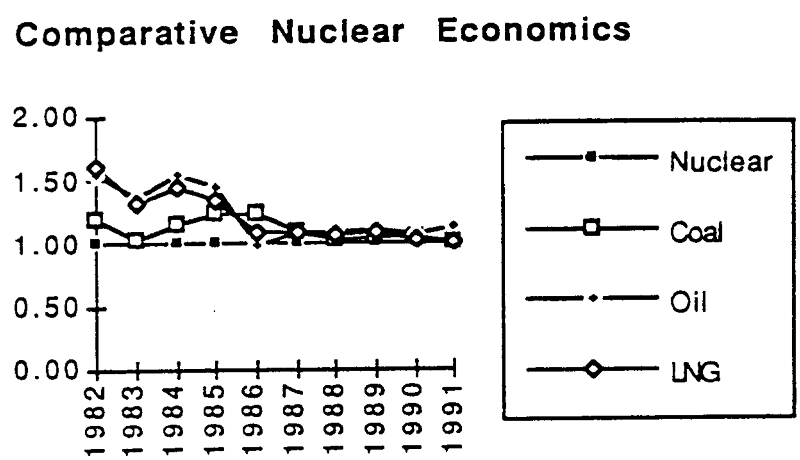
Table 3-6

Relative Cost of Nuclear Power
Estimated by MITI

	1985	1989	1992
Nuclear	1.0	1.0	1.0
Hydro	1.2	1.4	1.4
Oil	1.7	1.2	1.1
Coal	1.2	1.1	1.1
LNG	1.6	1.1	1.0

Source: MITI, 1985, 1989, 1992.

Figure 3-2
Relative Competitiveness of Nuclear Power
Estimated by IEE



Source: Yuasa, (1992), Institute of Energy Economics, 1992.

This seems to be a comfortable margin to make the cost penalty of reprocessing acceptable. However, there are various assumptions made in the estimate which could make the advantage much smaller. For example, the IEE calculated another scenario in which the price of oil is estimated to decrease to $15/bbl in 2000. In that case, the estimated power generation costs of electricity from coal and LNG would be ¥11.36/kWh and ¥10.75/kWh, and thus the cost advantages would be between ¥1.64/kWh (for LNG) and ¥2.25/kWh (see Table 3-7 and Table 3-8). Furthermore, the cost of fossil fuels is more sensitive to external factors, such as the exchange rate, than the cost of nuclear fuel. By changing the exchange rate from the assumed ¥130/$ in the IEE study to ¥85/$ and by taking the low fuel price case, the price gap between nuclear and LNG/coal would be narrowed to only ¥0.20 to 1.08/kWh.

What then would be the impact of the Rokkasho reprocessing plant? Since there is no public information available that gives a detailed breakdown of reprocessing costs in Japan, the OECD/NEA assumption must be used as a base for the estimate. In the calculation, we use a range of capital cost estimates, with the official capital cost estimate of ¥8,400 billion (published by JNFL) as the lowest number, ¥1.5 trillion as a medium, and ¥2.0 trillion as the high end.[49] Table 3-9 summarizes the results of the calculations. Assuming a lifetime capacity factor of 75%, the reprocessing cost is between ¥0.34/kWh and ¥0.82/kWh. Note that the costs are very sensitive to the capacity factor and that the historic lifetime capacity factor for reprocessing plants is much lower than 75%. In particular, due to Japan's "no plutonium surplus policy," it is possible that the Rokkasho plant will be operated at well below a 75% capacity factor. Figure 3-3 shows the sensitivity of the reprocessing cost to the capacity factor. For the medium capital cost case, for example, the reprocessing cost could go up from ¥0.61/kWh to ¥1.53/kWh as the capacity factor goes down from 75% to 30%. That would eliminate the estimated cost advantage of nuclear power over fossil fuels. Table 3-10 and Figure 3-4 show that nuclear power can lose its competitive advantage over fossil fuel (LNG in this case).

It should be noted again that the OECD/NEA cost assumptions are very conservative, and thus these estimates are also conservative. Even under these conservative assumptions, the Rokkasho project could raise the cost of nuclear power above the cost of power generated by fossil fuels.

Deregulation Pressure and Reduction of Capital Burdens

With current trends toward deregulation in Japan, utilities are under strong pressure to reduce their power generation cost, in particular the capital cost portion. High capital costs are believed to be a major reason that the average Japanese electricity rate (¥19.7/kWh [~22¢/kWh] in 1992) is the highest among industrialized countries and has not gone down despite significant appreciation of the yen. Japanese utilities have been building power plants and transmission lines to meet consistently rising demand, in particular peak demand. Between 1975 and 1992, total power demand increased from 428 billion kWh to 798 billion kWh, an average rate of 3.7% per year. Peak demand increased even faster from 72.5 GWe to 151 GWe, an average rate of 4.4% per year.[50] As a result, the utilities' total average load factor went down from 68% in 1970 to 56% in 1992. Although growth rates are expected to be lower in the future, utilities and MITI forecast that both power and peak demand will continue to grow in the next 20 years. Up to 2010, total demand and peak demand are estimated to grow at 2.1%/year each. The average load factor is expected to remain low at 57%.[51]

The capital debt burden to the utilities as a result of these trends has been steadily increasing. For example, the total debt of the electric utility industry rose from ¥24.0 trillion in 1987 to ¥30.6 trillion in 1992 (in current

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[49]Asahi Shimbun, January 9, 1994.

[50]Electric Utility Industry Council, June 1994, quoted in Matsui, K., "Shin-Enerugi Deta No Yomi-kata (How to Read Energy Data-revised edition)", Denryoku Shimpo-sha, July 1994.

[51]Agency for Natural Resources and Energy (ANRE), MITI, "Denryoku Sangyo no Ri-enjiniaringu (Re-engineering of Electric Utility Industry)", Denryoku Shimpo Sha, August, 1994.

Table 3-7
Nuclear Power vs Fossil Fuel

Estimated by IEE
(¥/kWh)

	1992			2000 (base)			2000 (low fuel)	
	Nuclear	Coal	LNG	Nu.	Coal	LNG	Coal	LNG
Capital	6.40	5.39	4.15	5.92	5.74	5.24	5.74	5.24
O&M	2.33	2.36	1.36	2.15	2.51	1.72	2.51	1.72
Fuel	1.48	3.23	4.74	1.49	3.35	4.59	3.11	3.79
Total	10.21	10.98	10.25	9.56	11.60	11.55	11.36	10.75

Assumptions:
(1) Construction cost : Nuclear ¥343,000/kW in 1992, ¥317,000/kW in 2000
Coal ¥276,000/kW, ¥294,000/kW
LNG ¥224,000/kW, ¥283,000 /kW respectively
(2) Nuclear Fuel cycle cost includes decomissioning and reprocessing but does not include the final disposal cost, Reprocessing price=30% of fuel cycle cost~ ¥0.45/kWh in 2000.

(3) Fossil Fuel Prices are linked to oil price. Base: Oil price= $20/bbl from 1990 to 2000.
Low: Oil price=decline from $20 to $15/bbl in 2000.

(4) Exchange rate: ¥130/$

Source: Compiled fromYuasa (1992).

Table 3-8
Nuclear vs. Fossil in 2000
(Without reprocessing, ¥/kWh)

		(Base)		(Low Fuel)		Cost Diff(Base)		(Low)	
	Nuclear	Coal	LNG	Coal	LNG	Coal	LNG	Coal	LNG
¥130/$	9.11	11.60	11.55	11.36	10.75	2.49	2.50	2.25	1.64
¥100	9.04	10.83	10.49	10.64	9.88	1.79	1.51	1.60	0.83
¥85	9.01	10.44	9.96	10.09	9.20	1.43	1.01	1.08	0.20

Source: Authors' estimate, based on data from Yuasa (1992).

Table 3- 9
Estimated Reprocessing Cost for the Rokkasho Plant

(¥ billion)

	Low	Med	High	OECD/NEA
Capital	840	1500	2000	554.9
O&M+Decomm.	864	1543	2057	570.6
life time total cost	1704	3043	4057	1125.5
Reprocessing Cost (¥/kgHM)	109,000	194,643	259,524	72,000
(¥/kWh) 75%	0.34	0.61	0.82	0.23
60%	0.43	0.76	1.03	----
45%	0.57	1.02	1.37	----
30%	0.85	1.53	2.05	----

Assumptions:
(1) According to the OECD/NEA estimate, the share of capital cost in total life time cost is estimated to be 49.3%. O&M and decommissioning cost and others' share is 50.7%
(2) For Rokkasho plant, capital cost is estimated to be ¥840 billion(low), ¥1.5 trillion (med) and ¥2.0 trillion (high).
(3) Average burnup rate for the Rokkasho plant is 40,000 MWD/ton.
(4) Reprocessing cost (¥/kgHM)=Total Rokkasho cost/Total OECD cost x Reprocessing cost by OECD/NEA (720 ECU=¥72,000 at ¥100/ECU).
(5) Reprocessing cost (¥/kWh)= Rep cost(¥/kgHM) /40,000 MWD/tx0.33x24 hr/day assuming lifetime capacity factor of Rokkasho reprocessing plant at 75%, 60%, 45% and 30% respectively. OECD/NEA assumption is 75%.

Source: Compiled from OECD/NEA, JNFL.

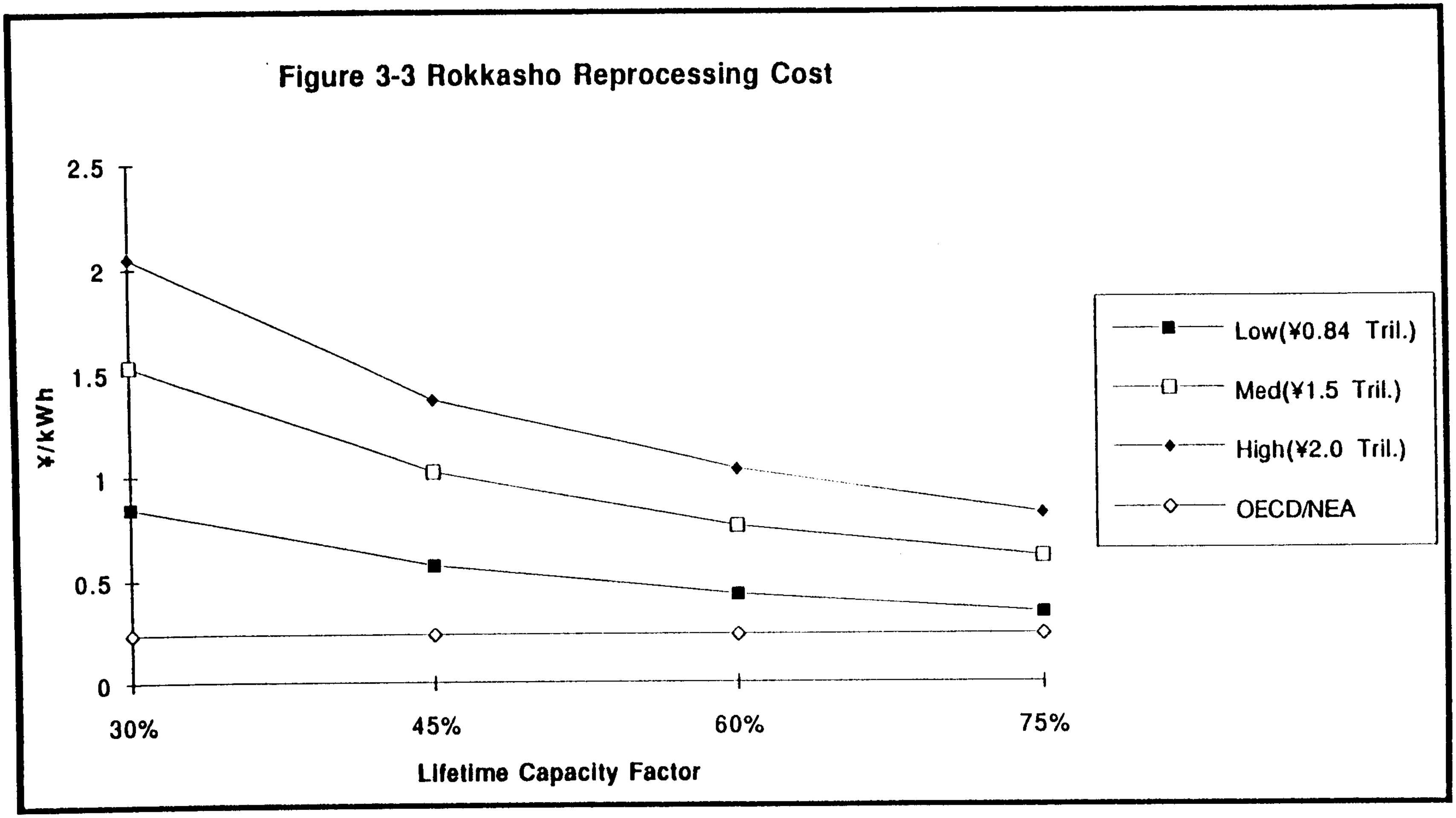

Figure 3-3 Rokkasho Reprocessing Cost
¥/kWh
2.5
2
1.5
1
0.5
0
30%
45%
60%
75%
Lifetime Capacity Factor
Low(¥0.84 Tril.)
Med(¥1.5 Tril.)
High(¥2.0 Tril.)
OECD/NEA

Table 3-10
Nuclear vs. Fossil

(¥/kWh, at 2000*)

Rokkasho lifetime capacity factor	Nuclear Power Rokkasho captial cost Low	Med.	High	LNG** Low	Base
	(¥0.84 t)	(¥1.5 t)	(¥2.0 t)		
30%	9.86	10.54	11.06	9.20	9.96
45%	9.58	10.03	10.38	9.20	9.96
60%	9.44	9.77	10.04	9.20	9.96
75%	9.35	9.62	9.83	9.20	9.96

* Exhange rate is assumed at ¥85/$
** Low fuel case: oil price at $15/bbl at 2000, Base case: oil price at $20/bbl at 2000

Source: Estimated by authors based on Yuasa (1992) and Rokkasho reprocessing cost estimates.

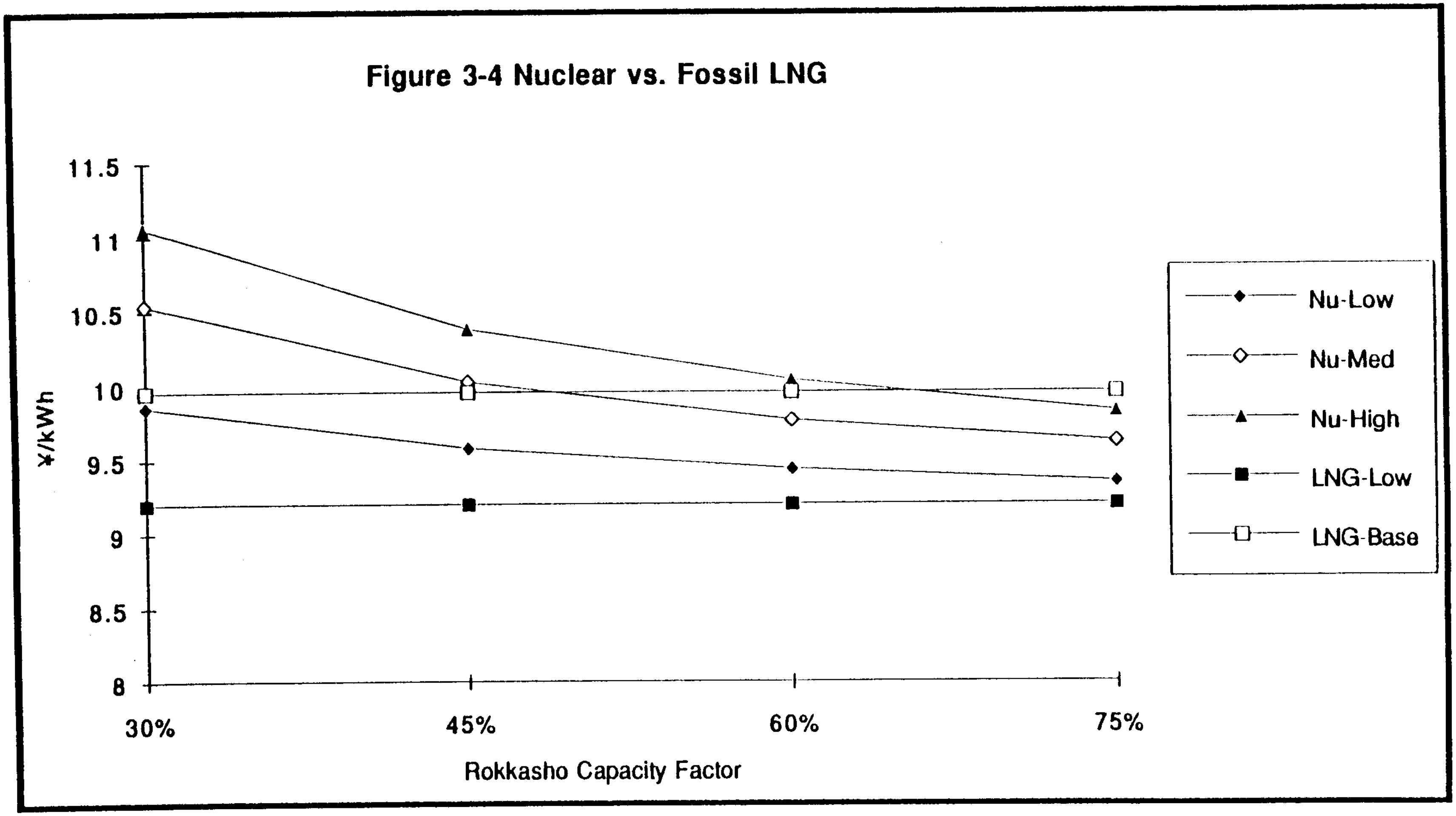

Figure 3-4 Nuclear vs. Fossil LNG
11.5
11
10.5
10
9.5
9
8.5
8
¥/kWh
30%
45%
60%
75%
Rokkasho Capacity Factor
Nu-Low
Nu-Med
Nu-High
LNG-Low
LNG-Base

value), and the debt/equity ratio rose from 4.74 to 5.38.[52] For Tokyo Electric Power alone, according to the report by the Nihon Keizai Shimbun, the cumulative total debt (long term and short term debt plus corporate bonds) will reach ¥10 trillion during this fiscal year, which is roughly 5.5% of *all* publicly listed debt of Japanese companies'. Annual interest payments in FY1995 are expected to reach ¥500 billion.[53] Capital lending agencies are concerned. In the Japan Development Bank (JDB), which primarily funds public projects, "energy and resources" represents the largest lending category (28%). In FY 1992, the Bank extended a total of ¥732 billion (~$8.6 billion at ¥85/$), out of which the nuclear share was ¥330 billion (~$3.9 billion). Although the fuel cycle portion is still small (¥76 billion, 10.3%), it is the fastest growing portion (42%/y from 1989 to 1992).[54] In addition, MITI introduced this year a law to deregulate the electric utilities in order to increase competition in the power industry. The law, which has been passed by the Diet, makes it easier for independent power producers to sell electricity to the wholesale market. The increased competition is expected to put additional pressure on utility companies to reduce costs.[55]

In fact, nuclear fuel cycle cost could become a target of cost reduction efforts. Currently, reprocessing cost in the electricity rate is treated as a "reserve", which is an estimate based on nuclear fuel used in the current fiscal year, that will be deducted when actual reprocessing takes place in the future. The reserve amount is naturally more than the actual reprocessing cost that utilities are currently paying, and thus the size of the reserve is growing. As of 1992, the total reprocessing reserve was estimated to be ¥1.16 trillion, and the actual reprocessing expense that fiscal year was only ¥0.04 trillion. Thus, it has become a source of criticism because of its effects on electricity prices.[56] Furthermore, Tokyo Electric Power has recently announced its intention to introduce an international bidding system for nuclear fuel procurement in order to reduce nuclear fuel cycle costs.[57]

Under these circumstances, it will be increasingly difficult to launch massive projects such as plutonium recycling and FBRs which require a series of large investments. In the next 20-30 years, according to present plans, utilities need to build a MOX fabrication plant for LWRs, three to four FBRs including a demonstration FBR(DFBR), and an FBR reprocessing plant, in addition to the Rokkasho reprocessing plant. It is understandable therefore that when utilities announced their commitment to build the DFBR, they set the capital cost cap at 1.5 times that of an LWR. No capital cost cap has yet been announced for the reprocessing plant. It is possible that the financial burden of capital intensive projects such as plutonium recycling could become a major problem for utility companies. This situation explains the recent request by the utilities not to build the DATR.[58]

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[52]Federation of Electric Power Companies (FEPC), "Denki Jigyo Binran (Data Book for Electric Utility Industry)," FY 1993 edition. September 1993.

[53]Nihon Keizai Shimbun, "Toden, Yurishi-fusai 10 cho-en daini (For TEPCO, corporate debt will reach ¥10 trillion)," May 12, 1995.

[54]The Japan Development Bank, Annual Report, 1993 edition.

[55]Uekusa M., "Denki Ryokin, Kyoso-de Teika Kitai, (Electric Utility Rate is expected to go down due to increased competition)," Nihon Keizai Shimbun, May 16, 1995.

[56]Hideo Niizeki, "Denki Ryokin No Nesage Ga Hitsuyo (Electricity Rate should be Reduced)," Asahi Shimbun, May 29, 1993.

[57]"TEPCO to Cut Management Costs by Introducing Principles of Competition, Eventually Procuring N-Fuel Through International Bids," Atoms In Japan, May 1995, pp. 4-5.

[58]"Giving Up the ATR: The Federation of Electric Power Companies Requests Change for Ohma Nuclear Power Plant," Nihon Keizai Shimbun, July 12, 1995, pp. 1&3. See also "Cancellation of DATR is reasonable," Editorial, Nihon Keizai Shimbun, July 13, 1995, p. 2.

C. Environmental Benefits

The third rationale for the closing of the fuel cycle is that the reprocessing of spent fuel will reduce the burden of radioactive waste management. This rationale is based on the expectation that the volume of vitrified high-level waste from reprocessing containing fission products and small amounts of actinides will be significantly smaller than the volume of the spent fuel itself. In addition, the removal of the plutonium from the waste would reduce the hazards of ingestion and inhalation of the waste in the long-term. These potential benefits, it is argued, could ease the difficulty of managing nuclear waste from the nuclear fuel cycle, and thus improve the political acceptability of nuclear power itself.

A natural extension of this reasoning is that it would be even more advantageous from the perspective of waste management to make a complete separation or partition of not only plutonium but all the minor actinides from the spent fuel, and recycle these long-lived radioisotopes as fresh fuel in a reactor where they would either be fissioned or transmuted to a stable species. The high-level waste for geologic disposal would then consist exclusively of fission products. The potential benefits of such a fuel cycle have led to R&D programs to develop the technology for actinide partitioning and recycling in France, Japan and Russia. A similar program in the US was recently terminated. However, the benefits of both standard reprocessing with plutonium recycling, and partitioning and recycling of all actinides have been questioned. Criticism has centered on the claim that reprocessing will reduce the volume of waste and reduce risks.

Waste Volume Reduction

Space requirements for geologic disposal of spent fuel or high-level waste are initially determined by cumulative heat loads generated by the waste rather than by the volume of the waste itself. The U.S. Department of Energy concluded: "The excavated capacity required in a repository for HLW or spent fuel would also need to cope with heat generation. As this is similar for both HLW and spent fuel, the repository capacity required for either HLW or spent fuel disposal would be similar."[59] For roughly the first hundred years after reactor discharge, heat generation is essentially a function of fission product, rather than actinide concentration. Table 3-11 shows that, for the first hundred years, fission products, especially Sr and Cs, are the dominant sources of cumulative decay heat. Therefore, unless wastes are stored for more than a hundred years before final disposal, high-level waste after reprocessing and spent fuel require roughly the same volume for geologic disposal.

The reprocessing/partitioning operation itself creates additional streams of transuranic low and intermediate level wastes which also require disposal. If the volume of the vitrified high-level waste(VHLW) coming from reprocessing is compared with the volume of spent fuel itself, the VHLW's volume is roughly 15% of the spent fuel itself (i.e. 85% volume reduction). In practice, however, reprocessing produces solid waste consisting of process materials, filters, containers, tools, rags, and a large volume of liquid waste. Some of the cladding and solid waste are contaminated with transuranics and other long-lived radioisotopes. These wastes may need long-term disposal as required for VHLW.[60] According to an estimate by COGEMA, an average volume of VHLW including such long-lived wastes is about 1.4 m^3/tons U, compared to 1.7 m^3/tons U in the case of spent fuel disposal, only about a 17% volume reduction. COGEMA estimates that volume reduction efforts could reduce the volume of VHLW to less than 1.0 m^3/tons U by 1995 and 0.5 m^3/tons U by 2000.[61] If so, the volume reduction would be as much as 70%. These COGEMA estimates, however, have not yet been demonstrated. In addition, they do not include waste from decommissioning of the reprocessing plant, which would increase the volume of both HLW and LLW significantly. Therefore, the benefit of reprocessing in terms of volume reduction appear marginal at best.

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[59]First Report from the Environment Committee Session 1985-86, vol. II, p. 554, quoted in Paul Davis, "The Case Against Reprocessing," in Frank Barnaby ed., "Plutonium and Security: The Military Aspects of Plutonium Economy," St. Martin's Press, New York, 1991.

[60]Nuclear Energy Policy Study Group, "Nuclear Power Issues and Choices," Ballinger, 1977, p. 248.

[61]J.P. Giraud, J.A. De Montalembert, "Spent Fuel Management in France: Reprocessing, Conditioning, Recycling," presented at the Waste Management Conference '94, February 27-March 3, 1994, Tucson, USA.

Table 3-11
Decay Heat of LWR Spent Fuel

(Watts/MTHM)

Year	Actinides	Sr and Cs	Other F.P.	Total
1	610	8270	3430	12310
5	280	1550	430	2260
10	280	940	80	1300
20	270	650	30	950
50	250	320	2	572
100	215	97	0	312
200	174	9	0	183
500	110	0	0	110

Source: Chang, Yoon and Till, Charles, "Actinide Recycling," Proceedings of the First MIT International Conference on the Next Generation of Nuclear Power Technology, October 4-5, 1990.

Reduction of Risks

It is unclear whether standard reprocessing or even actinide partitioning will significantly reduce the long-term hazard of buried waste. This hazard is a function both of the toxicity of the contained radionuclides in situ and the pathway from the waste to the environment. Further, any reduction in the hazard of buried waste due to standard reprocessing or actinide reprocessing/partitioning and recycle must be balanced against the increase in the operational risks to both employees and the public. Finally, R&D on actinide partitioning and recycling is still in an early stage, and it is unclear whether the required technology can be developed, and at what cost.

Perhaps the major difficulty of radioactive waste management comes from long-life radionuclides. Spent fuel contains both radioactive fission products (FP) and the actinides, including plutonium. Most of the FP, however, have relatively short half lives (~up to 100 years). So after a couple of hundred years, the relative radiological "toxicity" is largely determined by actinides. (See Figure 3-5)[62] Reprocessing can separate those actinides from spent fuel, and thus can reduce the radiological toxicity of radioactive waste quite significantly. Plutonium is one of the major actinides; removing plutonium from spent fuel does help to reduce long-term radiological risks.

The studies done in France (1982)[63] and Germany (1985)[64] on this subject are particularly important since both countries were strongly in favor of the reprocessing option at the time of the studies. Both studies examined the entire fuel cycle and reactor operation phase, not just the back end of the fuel cycle. The French study found that there are benefits in removing plutonium from spent fuel but there are still uncertainties about long term risks, in particular those involving minor actinides. It recommended studying all options including direct disposal and "advanced reprocessing" i.e. separation of minor actinides from reprocessing. The German study concluded that the once-through option seems to have a slight advantage in waste management over the recycling option but the difference is smaller than the scientific uncertainties. In France, the new Law on Radioactive Waste passed in 1991 now requires the government to conduct a comprehensive review of all waste management options, a review that is now underway. For other countries, such as Canada, U.S., and Sweden, where the once-through fuel cycle is the basic policy option, the scientific consensus is that direct disposal of spent fuel can be done safely.[65]

As the French study suggested, however, the natural extension of the present reprocessing option is to remove all actinides. This has become one of the major motivations for the Integral Fast Reactor project (and in particular, pyro-processing) in the U.S., and is becoming so in other countries, such as France and Japan. By removing all actinides (99.9% to 99.999%), radiological toxicities after 1,000 years or so would be substantially lower. Therefore, the strict supervision period during which the toxicity of HLW is greater than that of the uranium ore from which the HLW is derived after discharge from a reactor is reduced from the current 10,000-100,000 years to less than 1,000 years. In addition, as discussed above, the cumulative decay heat, which determines the space requirement, is also largely determined by actinides after a few hundred years. By removing actinides, it is estimated that a factor of 2 to 10 increase in depository capacity can be achieved assuming disposal

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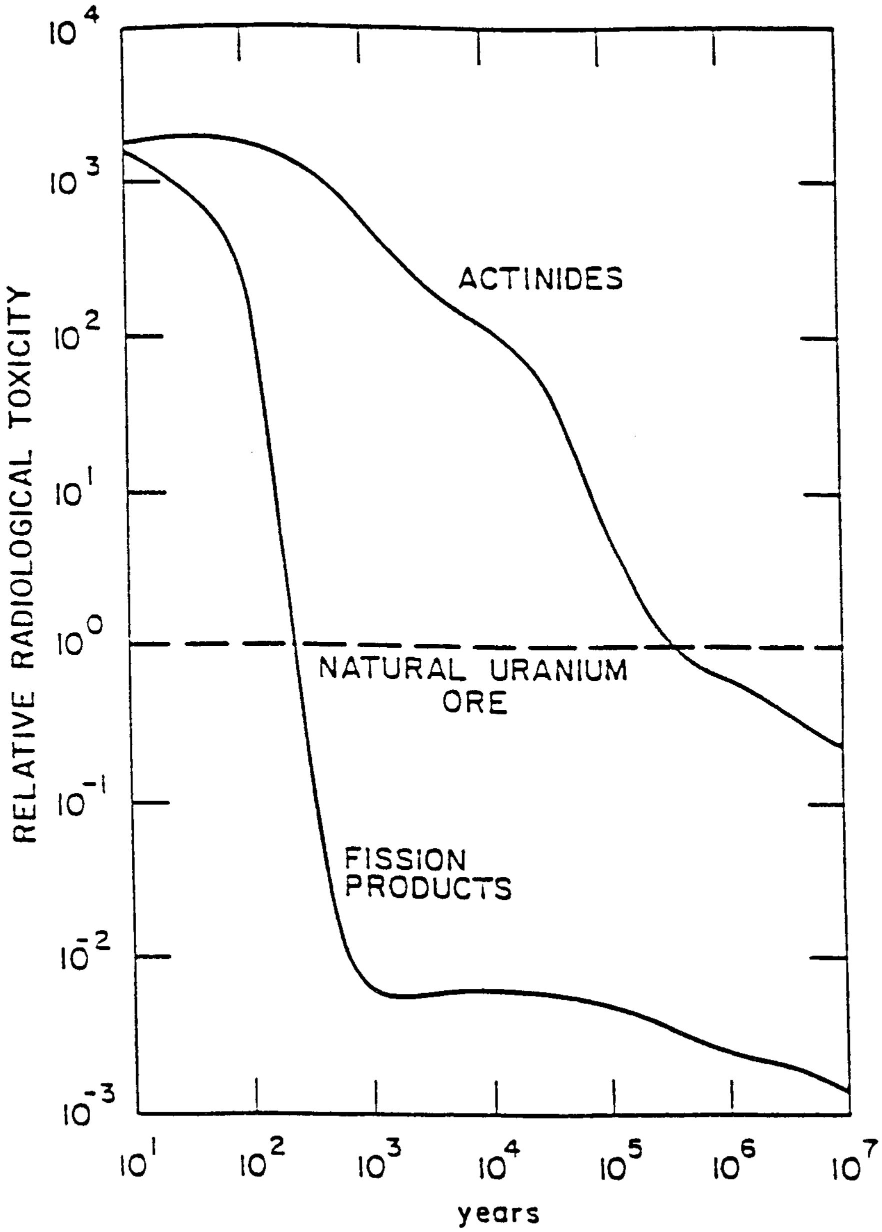
[62]Charles Till and Yoon Chang, "Actinide Recycle," Proceedings of the First MIT International Conference on the Next Generation of Nuclear Power Technology, October 4-5, 1990, Massachusetts Institute of Technology, MIT-ANP-CP-001.

[63]Report on Working Group on Spent Fuel Management to Supreme Council for Nuclear Safety, 1982. The report is called the "Casting Report," taking the name of the study chairperson.

[64]Karlsruhe Nuclear Research Center, "Systems Study: Alternative Entsorgung," Executive Summary, March 1985.

[65]See, for example, Commission on Geosciences, Environment, and Resources, National Research Council, "Rethinking High-level Radioactive Waste Disposal," National Academy Press, 1990. The report says: "There is a strong worldwide consensus that the best, safest long-term option for dealing with HLW is geological isolation."

Figure 3-5
Relative Toxicity, Based upon a Single Ingestion of High Level Radioactive Waste Constituents as a Function of Time following Radioactive Shutdown



Source: Chang, Yoon and Till, Charles, "Actinide Recycling," Proceedings of the First MIT International Conference on the Next Generation of Nuclear Power Technology, October 4-5, 1990.

after allowing FP to decay.[66] The proponents of actinide recycling argue that these benefits will improve the likelihood of public acceptance of waste depositories.[67]

However, others argue that the benefits of actinide recycling or reprocessing in general may not be as large as claimed. First, Ramspott et. al. suggests that there are other methods to increase repository capacity. For example, a combination of extended surface storage of spent fuel (about a few hundred years) as well as redesign of the repository itself could increase the capacity by a factor of 2 to 5 without actinide recycling.[68] Ramspott et. al. also pointed out that there may be disadvantages to heat reduction. For example, the loss of actinide heat generation can result in a repository cooling more quickly below the boiling point of water at a faster rate, thus making the repository conditions more susceptible to possible water contact.

Regarding the long-term risks, Pigford argues that "radiological toxicity" is not necessarily the best criterion for measuring waste disposal performance. He relies on the International Commission on Radiological Protection (ICRP), which estimates cancer risk to various body organs resulting from ingestion of a radionuclide. When this is multiplied by the number of curies of each isotope in the spent fuels, the relative radiological risks can be estimated from all radionuclides contained in the spent fuels. Pigford argues that radiation "dose risks" instead of "toxicity" should be used to assess the real risks of spent fuel or radioactive waste. Dose risks should incorporate factors such as actual release rates and pathways by which radioactivity would result in human exposure. Since some fission products such as technetium (Tc-99), iodine (I-129) and cesium (Cs-135) are much more soluble than actinides in water, actinides are less likely to determine the relative dose risks (Table 3-12). Therefore, removing actinides does not have a significant advantage over direct disposal in terms of relative dose risks.[69] Even if there would be certain benefits, removing actinides effectively has not yet been demonstrated.[70] There remains substantial uncertainty about the effectiveness of partitioning and transmutation which will only be answered through research over many years.

There has been little literature in Japan that compares once-through and reprocessing options on the basis of relative importance for waste management. But there has been an increasing number of scientific papers on the subject of actinide recycling, since Japan inaugurated the OMEGA project in 1987. The project, conducted at PNC and JAERI, is now officially endorsed as the "advanced fuel cycle technology project" in the JAEC's long-term program. Under current R&D programs, Japan intends to develop new reprocessing processes and to develop fuel cycles including actinide recycling for fast reactors, in parallel with existing traditional reprocessing using the purex process and disposal of vitrified HLW without partitioning and transmutation. Typically, the papers on actinide recycling emphasize the theoretical benefits but correctly recognize the considerable scientific uncertainty. For example, Ann (1995) points out that in order to reduce radiological risks

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[66]Ramspott, L.D., Choi, J., Halsey, W., and Pasternak, A., "Impacts of New Developments in Partitioning and Transmutation on the Disposal of High-Level Nuclear Waste in a Mined Geologic Repository," Lawrence Livermore National Laboratory, UCRL ID-109203, March 1992, p. 16-6.

[67]Charles Till and Yoon Chang, "Actinide Recycle," op. cit.

[68]Ramspott et. al., op. cit., p. 16-6.

[69]Pigford, T., "Actinide Burning and Waste Disposal," Proceedings of the First MIT International Conference on the Next Generation of Nuclear Power Technology, October 4-5, 1990, MIT-ANP-CP-001. A similar conclusion was reached by Ramspott et. al. (1992). They concluded: "For actinides which are solubility limited, their release in slow leach and migration is independent of inventory and thus unaffected by actinide burning... Actinide burning does not reduce the risk to the public from a geologic repository." pp. 16-19. Pigford does argue that there are benefits of reprocessing in general. Vitrified waste contains fission products better than spent fuel under certain circumstances, such as in a repository in unsaturated rock.

[70]The National Academy of Sciences has been studying this issue for about two years, but its report is not available at the time of writing.

Table 3-12

DOSE RISK FACTOR FOR UNREPROCESSED SPENT FUEL

Species	Half Life (years)	Repository Inventory (Ci/Mg)	Fractional Dissolution Rate (yr^{-1})	Dose Conversion Factor $\left(\frac{(rem)(m^3)}{(Ci)(yr)}\right)$	Relative Dose Index $\left(\frac{MfC_i}{MfC_{Tc}}\right)$
Fission Products					
Tc-99	2.12×10^5	1.30×10^1	2.5×10^{-4}	2.1×10^3	1
I-129	1.7×10^7	3.15×10^{-2}	2.5×10^{-4}	3.9×10^5	4.5×10^{-1}
Cs-135	3×10^6	2.14×10^{-1}	2.5×10^{-4}	1.7×10^4	1.3×10^{-1}
Actinides					
U-234	2.47×10^5	2.03×10^0	3.6×10^{-11}	3.7×10^5	3.9×10^{-6}
U-238	4.51×10^9	3.17×10^{-1}	3.6×10^{-11}	3.6×10^5	6.0×10^{-7}
Np-237	2.14×10^6	9.99×10^{-1}	1.1×10^{-10}	2.6×10^6	4.2×10^{-5}
Pu-239	2.44×10^4	3.05×10^2	2.0×10^{-11}	3.8×10^6	3.4×10^{-3}
Pu-240	6.58×10^3	4.78×10^2	2.0×10^{-11}	3.8×10^6	4.9×10^{-3}
Pu-242	3.79×10^5	1.72×10^0	2.0×10^{-11}	3.5×10^6	1.8×10^{-6}
Am-243	7.95×10^3	1.56×10^1	5.0×10^{-11}	3.8×10^6	4.3×10^{-4}

Notes:

Repository inventories are for PWR spent fuel, 33,000 MWD/Mg, at 1000 yrs

Source: Thomas Pigford, "Actinide Burning and Waste Disposal," Proceedings of the First MIT International Conference on the Next Generation of Nuclear Power Technology, October 4-5, 1990, MIT-ANP-CP-001.

of waste, further thickening of the engineering barrier of the canister could be as efficient as actinide recycling.[71]

In sum, an analysis of nuclear waste management in the literature suggests that there are many unanswered questions. Japanese arguments that support the benefits of reprocessing require additional research to determine whether the theorized benefits can be realized. It is true that the political acceptability of nuclear waste may be improved simply by implying that something useful is being done to reduce the dangers of the waste. However, if the underlying technology is eventually shown not to be valid, the political effect could reverse. In any case international criticism of the Japanese plutonium program has been stimulated by uncertain claims that have been made before the appropriate research is undertaken to determine whether the theorized benefits can be realized.

At this time, the claimed environmental benefits of all alternatives are uncertain. A compelling case cannot be made in favor of standard reprocessing with separation of plutonium, advanced reprocessing with complete partitioning of all the actinides, or direct disposal of spent fuel.

[71]Ann, T., "Chiso Shobun To Shometsu Shori, (Geological Disposal and Transformation)," Nihon Genshiryoku Gakkai Shi (Journal of Atomic Energy Society of Japan), Vol. 37, No. 3, 1995, pp. 181-183.

IV. UNDERRECOGNIZED BACKGROUND FACTORS

Circumstances have changed since the basic contours of Japanese reprocessing and breeder plans were first formulated more than 30 years ago. All the claimed advantages -- security, political, and economic -- that appeared initially to favor plutonium use have changed. Yet the rationales and main elements of the Japanese plutonium program have not changed. International apprehensions have been fueled by this mismatch between a changing context and a relatively static program.

This study argues that background factors that are common to Japan and most other countries may provide benign, if unflattering, explanations for the continuity of Japanese plutonium programs. These factors include local politics and the national commitment to nuclear power, the inertia of large organizations, industrial interests, and cultural factors. Lack of appreciation of these factors outside Japan contributes to criticism of Japanese programs, as skepticism about official rationales fuels apprehension over proliferation risks.

While the scope of this study did not make it possible to investigate these factors in detail, we observed much evidence of their existence. They are typically not presented in policy documents, yet they may be of great importance in influencing decisions, especially for mature programs with long-standing multinational commitments and monetary investments. If such factors were more visible outside Japan as a result of a more transparent policy process, or were acknowledged in some way, international criticism might be significantly muted.

A. Law and Local Politics

As a result of legislation, government programs, and community attitudes, the reprocessing of spent fuel as a means of managing nuclear waste became in effect a prerequisite for the siting of nuclear power plants in Japan. There were legal and political reasons for Japanese utility companies to commit to reprocessing. The nuclear plant siting law required utilities to specify in advance their disposal methods for spent fuel, while local communities in turn have insisted on early removal of spent fuel as a condition for accepting nuclear plants. Since the JAEC long-term plan specified that reprocessing/recycling is an "essential" aspect of Japan's nuclear programs, in part as a necessary step in waste disposal, the utilities had relied on the availability of reprocessing as the only legal basis for operating nuclear power plants.

Utilities are required to specify the "disposal method" of spent fuels by the Law Concerning Nuclear Materials and Reactor Regulation (Article 23, items 3-8).[1] The more detailed rules of nuclear licensing (Rules Concerning Siting and Operation of Commercial Reactors, Art. 2, item 5),[2] which require specification of the disposal method, mandate that utilities specify "the methods and the other (contracted) party for the sales, loans, returns etc. of spent fuels as well as the methods of disposal." Since the final disposal method could not yet be specified, "reprocessing and storage of vitrified waste" was accepted as the "disposal method." Therefore, specifying the reprocessing company that would accept spent fuels was a necessary condition for new reactor licensing. Moreover, since local communities were resistant to long-term storage of spent fuels, there was pressure for early reprocessing.

Not only is reprocessing required for disposal of spent fuel, but the JAEC's long-term program specified that closing the nuclear fuel cycle is an "essential" part of Japan's nuclear programs. It was believed that reprocessing of spent fuels had to be carried out as early as possible, and that the utility companies had to have a site for spent fuels which would be reprocessed after a certain cooling period. Thus, reprocessing became embedded in the overall nuclear program for legal, political and pragmatic program reasons. "A mansion without a toilet" is the phrase often used by anti-nuclear groups to characterize the Japanese nuclear programs

[1]Kaku-nenryo busshitsu, kaku-gennryo busshitsu, genshiro no kiseini kansuru horitsu (Law concerning nuclear materials and reactor regulation), Law # 166, 1957.

[2]Jitsuyo Hatsuden-yo Genshiro-no sechi, unten, to-ni kansuru kisoku (Rules concerning siting and operation of commercial reactors), MITI rules # 77, 1978 (originally included in more general rules enacted in 1957).

during the 1970s, since no definite waste management plan was announced.[3] By the late 1970s, it was clear that utilities needed to find possible sites for low level waste (LLW) and vitrified high level waste (HLW) after reprocessing. In 1980, Japanese utilities established two companies, Japan Nuclear Fuel Service (JNFS) and Japan Nuclear Fuel Industry (JNFI). JNFS was a reprocessing company and therefore was also responsible for HLW storage until final disposal methods could be determined. JNFI was responsible for both LLW and the uranium enrichment business. The two companies eventually merged as Japan Nuclear Fuel Limited (JNFL) in 1992.

Since its establishment in 1980, the most important task for both JNFS and JNFI was to find sites for their fuel cycle facilities, i.e. LLW storage/disposal, uranium enrichment, and reprocessing (including spent fuel and HLW storage). It was natural to search for a potential site which could host all three nuclear fuel cycle facilities. Meanwhile, the utility industry felt partially responsible for the Mutsu Ogawara and wanted to do something to help the region (see the detailed discussion below).[4] Moreover, the Mutsu Ogawara project had already acquired more than enough land area for the nuclear fuel cycle facilities making it unnecessary to negotiate with the local community for the purchase of land, a big advantage over other potential site candidates. For these reasons, Rokkasho became the favored candidate for hosting the three nuclear fuel cycle facilities.[5] The three facilities were treated as one package, often called the "San-ten setto (Three-unit set)". In particular, reprocessing and uranium enrichment were considered particularly important by the community since without them Rokkasho would become only a nuclear waste site, positively the last thing the local community wanted. Both the mayor of Rokkasho and the governor of the prefecture repeatedly confirmed this position. In accepting the vitrified HLW from Europe, Aomori Prefecture and Rokkasho village specifically required that "the term for management of vitrified HLW will be no more than 50 years from the time of acceptance at the center."[6] Most recently, a newly elected governor of Aomori prefecture refused to unload vitrified HLW returned from Europe until he was reassured by the Government that "Aomori prefecture will not become a permanent disposal site without the Governor's consent."[7]

In order to mute the criticism of a mansion without a toilet, and to realize the long-term goal of "closing the nuclear fuel cycle," the Rokkasho project also became critically important for the Government. For the JAEC, it has been the cornerstone of the nuclear power program since the beginning of the long term program. For MITI, it is also needed to facilitate the siting of nuclear power plants. Both STA and MITI supported the utilities efforts to gain local support for the entire Rokkasho project. It became customary for the Minister of

[3]Quoted in Takeuchi, E., "Genshiryoku Hatsuden no Hanashi (Story about Nuclear Power)", Nihon Denki Kyokai Shinbunbu (Newspaper Division, Japan Electric Association), October, 1989.

[4]Mr. Sho Nasu, the president of Tokyo Electric Power and later a Chairman of Federation of Electric Power Companies, was quoted saying, "We were thinking that we are partially responsible for such a vast open land area (in Rokkasho village)...We would like to build a Mecca of science and technology, like the Tokai village.." see Teramitsu, T., "Aomori Rokkashomura (Rokkasho Village, Aomori)," Mainichi Shinbun, Feb. 1991, p. 146.

[5]There are other candidates for nuclear facilities around the area. Higashi-Dori village, located next to Rokkasho, was negotiating with Tokyo Electric and Tohoku Electric to be the site for 4 to 10 nuclear power plants. In 1993, Higashi-Dori agreed to host 4 nuclear plants. Electric Power Development Corporation (EPDC) negotiated with Ohma village, in the western part of Aomori prefecture, as a site for the recently cancelled Demonstration ATR.

[6]"JNFL and local bodies to negotiate for safety pact on HLW storage center," Atoms in Japan, July 1994, p. 22.

[7]Genshiryoku Sangyo Shimbun (Atomic Industry News), April 27, 1995. Former Governor of Aomori, Mr. Kitamura, also demanded a similar guarantee before his re-election bid last November. The Minster of STA released a written statement confirming the government position that "the selection of a candidate terminal disposal site could not be carried out without the approval of local communities, and that the respective governor's intentions would be respected to the full degree." (Atoms In Japan, "STA promises not to make Rokkasho a terminal HLW disposal Site," November 1994, p. 18.)

STA (also the Chairman of JAEC) to visit Rokkasho as soon as he or she became Minister. In sum, the Rokkasho project became a "national project." Both the Government and the utilities came to see the stakes as so high that failure of any part of the program could put the entire nuclear power program in jeopardy.

Rokkasho village is located on the Pacific Ocean side of Shimokita Peninsula which is the northern edge of Honshu Island. The village has a larger area (253 km^2) than Osaka city with only a small population (~12,000). Because of the strong cold wind from the east, the village's farmers often have a poor yield of their main products, rice and potatoes. The Aomori prefecture itself was the fourth poorest prefecture in Japan, and many farmers are forced to seek non-farming jobs during the off-harvest periods. The area was once called the "Siberia of Japan." Given its agricultural barrenness, it has been a long-held dream for Rokkasho village and for Aomori prefecture to invite large industrial projects to the region. In 1969, the government designated the "Mutsu-Ogawara area", of which Rokkasho was the main village, as one of the sites for the "New National Comprehensive Development Plans." The plan was to build a large petrochemical industrial complex in the area as part of the "Mutsu-Ogawara project." The Aomori Government was enthusiastic about the project. In 1971, Governor Takeuchi announced the outline of the project as follows.[8]

- Total development area would be 17,500 ha
- Total industrial output would be 5 trillion yen
- Total number of employees would be 100,000
- Main industry complex would consist of steel and petrochemical industry

The project would require the relocation of about half the village. Government and industry founded two companies, "Mutsu Ogawara Development Co." and "Mutsu-Ogawara Development Public Corporation" to be responsible for land acquisition.

However, what happened shortly thereafter fell considerably short of fulfilling this ambitious blueprint. Two major external events forced the project to shrink. One was the "dollar shock" in 1971 and the other the "oil crisis" in 1973. Because of these events, Japan's economy experienced a severe recession, forcing industry to rethink its commitment to the project. There was also opposition from the villages because of the need for large scale "reallocation" of housing. By 1977, the project was formally cut back. The total development area decreased to about one-third of its original area (~ 5,000 ha), and the steel industry project was cancelled, leaving the petrochemical plants and fossil power plants as the main industry projects. The land acquisitions proceeded despite the growing uncertainty about the entire project. The "new residential area" for the relocated families was completed by 1976 and other basic elements of the infrastructure, such as the main road and schools, were also established by 1978. Still, none of the industrial projects came to fruition. In 1978, the government decided to build a national strategic petroleum stockpile facility in order to salvage the project. It was built by the National Petroleum Corporation, completed in 1979, and was the only major facility completed before the nuclear fuel cycle project was introduced. Mutsu Ogawara Corporation owned 2,800 ha of land, but the petroleum stockpile facility used a mere 260 ha. About 90% of the land was unused. The total population of the village, once planned to be around 300,000, never exceeded 13,000. Needless to say, the Mutsu Ogawara project was a large disappointment for Rokkasho village as well as for Aomori prefecture.

The three nuclear fuel cycle facilities, however, have already brought significant economic benefits to Rokkasho village as well as to the Aomori prefecture. The most concrete and visible benefits are in the form of compensation payments. There are two kinds of compensation. One is "kofu-kin" (tax subsidy) under the three basic laws to promote siting of electric power facilities which are paid indirectly by the utilities. The other is "hosho-kin" (compensation money), paid directly by the utilities. The hosho-kin is usually a one-time payment to the community whose jobs (usually agriculture or fishery) would be affected by the project. The amount is decided during negotiations between the community and the project management companies. The kofu-kin is an annual payment to the community during the construction period of the project. The amount is determined by law but is proportional to the size of the project. It should be noted that both payments are made *before* commercial operation of the project begins. Usual economic benefits, such as taxes paid to the community, come after project startup.

[8]Sakamoto, T., "Shimokita Purutonium Hantou (Shimokita plutonium peninsula)," Asahi Shimbun, Feb. 1994, p. 48.

The hosho-kin for the Rokkasho village was already decided when the Mutsu Ogawara project was accepted by the community.[9] Although the community could have negotiated anew with the utilities for accepting nuclear fuel cycle facilities, both the governor and the mayor accepted the existing amount of compensation and both welcomed the project. The total amount received in 1979 was ¥13.0 billion. However, opposition from the Tomari village fishermen was strong. They had received compensation from the Mutsu Ogawara project but demanded more for the nuclear fuel cycle project. Negotiations lasted longer than expected and delayed the project significantly.

Since the three basic laws which specify the kofu-kin were originally written for power plant siting, nuclear fuel cycle facilities were not included as the subject of kofu-kin. In 1987, MITI amended the law to include those facilities. The original formula used to calculate this amount was based on the "power plant capacity," and was thus not appropriate for the nuclear fuel cycle facilities. MITI decided to create an "equivalent capacity number" for each facility so that kofu-kin could be calculated based on a formula.[10] Based on the formula, the total amount of kofu-kin is about ¥42.3 billion. As can be seen in Table 4-1, almost 80% of that amount comes from the reprocessing plant (¥8.7 billion for the enrichment and LLW facility, and ¥33.6 billion for the reprocessing plant). Furthermore, about 45% of the total (~¥19 billion) goes to Rokkasho village; the rest will be given to the surrounding community and the Aomori prefecture. As of the end of FY 1992, about 25% of total kofu-kin had been paid to the local community.[11] MITI also gave special treatment by allowing "early payment" of kofu-kin to the community. The law specifies the payment period from the "startup of construction" to "five years after the completion of the plant," but MITI allowed payment to start "two years before the start up the construction."[12] MITI also published in 1988 an optimistic estimate of the economic impacts of the nuclear fuel cycle projects on the regional economy. According to the estimate, the total economic "spin-off" from the project could reach ¥750 billion, and the project could produce new employment of 3,000 people per year.[13]

The economic impact of these payments on the regional economy is clearly visible in the area. The roads have been paved and widened, and welfare facilities such as a gymnasium were built by the compensation fund. The fiscal impact on Rokkasho village has also been significant. For example, the total FY 1990 budget proposal of Rokkasho village was about ¥5.1 billion, and the income from compensation was ¥0.9 billion. Thus, roughly 20% of the total village income that year came from the compensation payments, and this was even before construction started.

Since the kofu-kin will eventually expire (5 years after the plant is completed), there will be additional tax revenue based on the nuclear fuel. The tax, known as "Nuclear Fuel Material Handling Tax," is currently rated as ¥7,100 per kg of enriched uranium and ¥29,800 per m^3 of radioactive waste to be buried. The tax revenue goes to the prefecture and can be used to support local infrastructure development, such as road and port construction. On July 30, 1991, as the operation of uranium enrichment and LLW facilities were about to start

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[9]Land sale is another economic benefit from the project. It is reported that the land prices of Rokkasho area soared more than 200 times in 1973. But the land sales from Mutsu Ogawara to JNFS/JNFI for the nuclear fuel cycle facilities did not bring any benefit to the local community, while the prices again soared about 20 times, ibid., pp. 53, 180.

[10]MITI decided that three facilities are equivalent to 4,000 MW in total. Personal contact, December 1993.

[11]Numbers are given by the "siting coordination office" of MITI nuclear industry division, February 1994.

[12]See Sakamoto, T., op. cit., p. 73. There are additional kofu-kin payments to the Aomori Prefecture. For the prefectures whose power output is more than 1.5 times that of its consumption, the Government pays a special kofu-kin ("Power export preferential payment") to those prefectures. Since the reprocessing plant is also now regarded as a "power facility" and its construction started this fiscal year, Aomori prefecture will receive ¥600 million annually from the next fiscal year. (Daily Tohoku, February 13, 1994.)

[13]MITI, "Study on Social Environment of Nuclear Fuel Cycle Facilities," quoted in Sakamoto, T., op. cit., p. 108.

Table 4-1
Economic Benefits to the Local Community*

Rokkasho Village and Aomori Prefecture

(¥ million)

	Reprocessing	LLW/ Enrich.	Total**
Rokkasho	14,890	4,266	19,156
Vicinity Towns***	15,321	4,203	19,523
Aomori Pref.	3,389	215	3,604
Total	33,600	8,684	42,284

* Under the Power Plant Siting Promotion Laws
** About 30% of total amount has been paid by 1992.
*** 14 Cities/towns and associations

Source: Ministry of International Trade and Industry

in 1992, the Ministry of Home Affairs approved the Aomori Prefecture's application for the tax revenue. The Aomori prefecture estimated that the nuclear fuel tax would generate ¥6.7 billion for the five years beginning in the fiscal year 1992.[14] Once this large compensation is built into the local economy, it is evident that it would be extremely difficult for either promoting organizations or the community to revise the plan.[15] Though there has been some community opposition to the nuclear project in the past, the project now appears to be accepted, with the economic benefits to the village and Aomori prefecture already substantial. Any change in scope of the project, especially one that would leave the waste site but delete the reprocessing plant without substituting other significant activities, would most assuredly stimulate local opposition.

The significance of the utilities' statutory need for formal nuclear waste disposal options, the local political unacceptability of waste disposal without other activities, and the economic benefit to the local community is not fully appreciated abroad. Yet it is because of these factors that reprocessing has become embedded in the overall nuclear program, quite independently of cost and benefit calculations. These legal and institutional factors could change. Now that the JAEC long term program officially endorses long term spent fuel storage, the utilities may no longer need to view reprocessing as an immediate requirement for spent fuel management.

B. Organizational Inertia and Decisionmaking Processses

Large organizations and complex decisionmaking processes have a natural inertia that makes significant policy change, especially reversal of policy, difficult to accomplish. The JAEC's long-term programs and development policies (called "kihon hoshin" or Basic Guidelines) have a strong influence over all nuclear-related activities. The policy making process of JAEC is carefully crafted so that "consensus" among interested parties can develop. The range of organizations, the array of legal constraints, and the complexity of decisionmaking processes are little understood outside of Japan.

Fast breeder reactors and reprocessing are considered "national" projects, for which both government agencies and private industry have made major institutional commitments over many years. Project budgets and personnel cut across public and private organizations. The commitment to plutonium is not confined to Japan. The vision of low-cost abundant energy has been held by many other countries as well (France, Russia, India) and is not easily abandoned, especially when large international commitments have been made.

The formulation of the JAEC's long-term plan involved three key government agencies (STA, MITI and MOFA), two national research organizations (PNC, JAERI), the nuclear suppliers industry, and most of the utilities. There are four JAEC posts typically held by retired officials from government agencies, universities and private industry. The JAEC has 10 permanent committees each of which consists of academic experts, industry representatives and sometimes includes non-technical experts. In addition, under the committee on the long-term program, the JAEC has various sub-committees. The formulation of each revision of the long-term program takes typically one to two years. The latest 1994 long term program took even longer than two years. This large and complex decision making process itself almost guarantees the conservative nature of the resulting decisions. Even if there is understanding that conditions have changed and programs ought to be altered, that change can only be accomplished gradually.

The flexibility of individual organizations within this constellation is further reduced when narrow organizational missions and roles are specified by law. The legally binding, rigid and specific allocation of responsibility for energy research across PNC, JAERI, the Central Research Institute for Electric Industry (CRIEPI), and MITI-affiliated New Energy and Industrial Technology Development Organization (NEDO) builds in inertia and inefficiency. If specific organizations are limited by law to the investigation of specific technologies, then reassessment and adaptation are discouraged.

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[14]JAIF, "Excerpts from Atoms in Japan," op. cit., p. 49.

[15]ibid., p. 48. For example, when the construction schedule of the reprocessing plan was delayed several times, the local authorities requested an additional subsidy to finance the local development projects which were supposed to be financed by the kofu-kin.

Table 4-2
Ownership of Japan Nuclear Fuel Limited
(original share, as of 1980)

Groups	Companies	Stocks (1,000)	Share (%)
Utility	Tokyo, Kaisai, Chubu Tohoku, Kyusyu, Chugoku Shikoku, Hokkaido Hokuriku, Japan Atomic Power	684.97	68.50
Banks	Dai-ichi Kangyo, Fuji, Mitsubishi Sumitomo, Sanwa, Mitsui, Long-term Credit, Nihon Kogyo, Sumitomo Trust, Mitsui Trust, Yasuda Trust, Mitsubishi Trust, Nippon Saiken, Kyowa Bank Taiyo Kobe, Tokai, Daiwa, Hokkaido Takushoku Tokyo, Saitama, Toyo Trust Chuo Trust, Nihon Trust	81.97	8.20
Construction	Obayashi, Kumagaya, Kashima, Goyo Sato Kogyo, Shimizu, Taisei, Takenaka Toda, Asuka, Nihon Kokudo, Hazama Maeda Kensetsu, Mitsui Kensetsu,	57.99	5.80
Insurance	Sumitomo Marince & Fire (M&F), Taisho M&F,Taisei M&F, Tokyo M&F Nihon M&F, Nissan M&F Nishin M&F, Yasuda M&F	30.99	3.10
Machinery	Chiyoda Kako, Nikki, Toyo Engineering Mitsubishi Heavy Industry, Ebara Niigata Tekko, Nihon Seiko	25.99	2.60
Cement	Nihon Cement, Chichibu Cement Onoda Cement, Sumitomo Cement Mitsubishi Mininig and Cement	24.99	2.50
Iron & Steel	Kobe Steel, Nippon Steel, Sumitomo Steel NKK, Kawasaki Steel	18.99	1.90
Trading Co.	Mitsubishi, Mitsui, Ito & Co Marubeni, Nishho Iwai, Sumitomo	17.99	1.80
Chemical	Asahi Kasei, Asahi Glass, Ube Kosan Sumitomo Chemical, Toray, Mitsui Toatsu Mitsui Petrochemical, Mitsubishi Kasei	15.99	1.60
Electric	Hitachi, Toshiba, Fuji Electric Mitsubishi Electric	13.99	1.40
Shipbuilding	Ishikawajima Harima Industry Kawasaki Heavy Ind., Mitsui Shipbuild. Sumitomo Heavy, Hitachi Shipbuild.	12.99	1.30
Mining	Mitsubishi Metal, Sumitomo Metal & Min. Nihon Kogyo, Mitsui Metal & Min.	10.99	1.10
Others	Nihon Gaishi, Individual	2.16	0.22
Total		999.8	100.0

Source: Tatsuro Ihara, "Genshiryoku Ohkoku No Tasogare (Twilight of Nuclear Empire)," Nihon Hyoron Shya, 1984.

Table 4-3
Future Prospects of Nuclear Industry Market

(¥ Trillion)

	1991-2000	2001-2010	2011-2020	2021-2030
Nuclear power Construction	5.9 (44.4%)	7.0 (38.3%)	7.5 (32.6%)	11.6 (32.4%)
Decomissioning	–	–	–	0.4 (1.1%)
Maintenance	3.5 (26.3%)	5.4 (29.5%)	7.6 (33.0%)	9.6 (26.8%)
Fuel Cycle	3.9 (29.3%)	5.8 (31.7%)	7.9 (34.3%)	14.2* (39.7%)
Total	13.3 (100%)	18.3 (100%)	23.0 (100%)	35.8 (100%)

Assumptions

* includes FBR reprocessing plant and HLW final disposal facility (estimated to be ¥ 4.3 trillion in 2021-2030, ~12.0%).

- nuclear capacity growth: 51GW (2000), 72.5 GW (2010), 100 GW (2030), in addition, DATR, DFBR, and a couple of FBRs are expected to built to 2030.
- uranium enrichment: In addition to the current plant (1500 ton SWU/y) the second plant will start operation by the beginning of 21st century.
- reprocessing plant: In addition to Rokkasho (800 ton/y), the second plant will be expected to start operation by 2010. Note that this plan has been postponed in the new long-term program.
- other fuel cycle facilities: FBR reprocessing plant, MOX fabrication plant, final HLW disposal facility.

Source: Japan Atomic Industrial Forum, 1992.

The result of these factors can be seen in the maintenance of the long-term commitment even while gradually stretching out the planned recycling programs. Incremental changes to the program, repeated slippage of large project schedules, and cancellation of small projects have not been well recognized by foreign observers.

Officials believe that the consistency of governmental commitment is important for both planning purposes and the maintenance of orderly governmental processes so as not to put into question the validity of past or future commitments. This attitude is not unique to Japan, nor to nuclear energy policy making. There is much social-psychological literature on the nature of decision making by organizations or individuals and how they each can become locked into a specific course of action. A typical example is found in Staw who summarizes two basic explanations of decision making behavior: "self justification" and "norms for consistency".[16] Staw argues that each individual tends to have a bias in decision making so as to justify previous behavior as well as future actions. In a social setting, in particular with government officials who may face external criticism, Staw says:

> "Individuals may be motivated to prove to others that they were not wrong in an earlier decision...administrators who implement a policy they know will be unpopular would be especially motivated to protect themselves against failure...[such an administrator] would most likely attempt to save a policy failure by enlarging the commitment of resources."[17]

In addition, Staw also argues that based on extensive surveys, norms for consistency in action are another major source of commitment. The results of those surveys showed that "administrators were rated highest when they followed a consistent course of action and were ultimately successful."[18] Case studies of large organizations and large scale projects show a similar tendency of continuous commitment. The findings are consistent with the theory suggested by Staw. For example, Hargrove studied the Tennessee Valley Authority and its commitment to large scale dam and nuclear plant projects.[19] He concludes:

> ".. The decision to deploy resources to their full use is not an isolated choice but a reflection of a large pattern that, if reversed, would call the rationale for the entire organization into question. Not only past but future decisions must be protected from such questioning....The escalation of commitment...is understandable as an effort to justify the rationale of earlier decisions....This may be a psychological element in the determination of leaders, for they wish to prove themselves to have been not only right but consistent."[20]

The unchanged Japanese commitment to plutonium projects most certainly has been influenced by pressures such as these.

The natural conservatism of the policy process is accentuated when the process is closed, providing little information to those outside the process. That has been the case with Japanese nuclear policy in the past, as a result limiting debate among all interested parties, and discouraging open comparison among alternative policy choices. There are many signs of improved openness of the nuclear decisionmaking process in Japan.

* In 1993, JAIF and CNIC co-sponsored a public symposium on plutonium: The Japan Atomic Industrial Forum (JAIF), a nationwide nuclear industry association, and the Citizen's Nuclear Information Center (CNIC), a leading anti-nuclear organization, agreed to co-host the symposium which was held on September 25, 1993 in Osaka, on the basis of "equal partnership". This was an unprecedented event in Japan, although public debate hosted by mass-media had taken place in the past, and both JAIF and CNIC commented positively on the

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[16]Staw, B. M., "The Escalation of Commitment To a Course of Action," Academy of Management Review, Vol. 6, No. 4, 1981, pp. 577-587.

[17]ibid., p. 580.

[18]ibid., p. 581.

[19]Hargrove, E.C., "TVA: Prisoners of Myth: The Leadership of the Tennessee Valley Authority 1933-1990," Princeton Studies in American Politics, Princeton University Press, 1994.

[20]ibid., p. 289.

result.[21] A similar public debate was held on November 12, 1994, in Osaka. This one was sponsored by the Japan Federation of Bar Associations. The Federation's Committee on Environmental Pollution Prevention, which had been critical of Japan's plutonium programs, had issued a statement the previous May calling for the immediate suspension of the plutonium policy.[22]

* A public hearing for JAEC's long-term programs was held on March 4 and 5, 1994, the first time it had done so. Prior to the hearing, the JAEC placed a full-page advertisement in national newspapers to encourage public participation. More than 6,000 letters were sent to the JAEC asking for more information. About 3,300 letters containing opinions were received. The JAEC invited various groups of people ranging from experts in international politics to anti-nuclear activists who were selected from those who sent letters. In addition, several were chosen by lottery to have an opportunity to express their opinions. The media reported that the views of the public toward the use of plutonium were "generally more critical than its attitude toward nuclear power using uranium fuel."[23] Although it is not clear how those opinions were actually reflected in the final long-term programs, the hearing was a positive step toward more open nuclear policy making.

These trends are not necessarily unique to nuclear power. For example, there have been a series of "roundtable" discussion on the Narita Airport expansion between the government and opponents. These discussions led the Government (Ministry of Transportation) to withdraw their original plan, and, in an unprecedented step, promised to start a new plan with closer dialogue with local groups. Similar efforts were made in the controversial Nagara-River dam project.

C. Industrial Interests

The Rokkasho project, which includes an enrichment facility, a low-level waste depository, a reprocessing plant, and a high-level waste facility, is already one of the largest in Japan. Ashai Shimbun reports capital costs of the reprocessing plant alone in excess of ¥2.0 trillion, even larger than the Kansai international airport (¥1.45 trillion) and the Trans-Tokyo Bay Road (¥1.46 trillion).[24] The participants in the Rokkasho project include almost all major industrial groups in Japan, as well as the French nuclear supplier industry. As Table 4-2 suggests, the industrial stakes in Rokkasho are substantial indeed, and are an important a factor in determining policy. Furthermore, since the new long-term program postpones the decision to build the next commercial reprocessing plant after Rokkasho until 2010, uncertainty over the future nuclear fuel cycle market is increased. The relative importance of the Rokkasho project has thus become even more important for the nuclear industry.

According to the recent JAIF study[25], the industry is optimistic about future nuclear market growth because the fuel cycle business will offset a slower growth rate in power plant construction. Table 4-3 shows that the total market during the 2020s (2021-2030) will reach ¥35.8 trillion, about 2.7 times the current (1991-2000) market (¥13.3 trillion). The "construction market" (defined mostly by reactor construction) will grow from ¥5.9 trillion to ¥11.6 trillion, still significant growth but slower than the total market growth. As a result, the construction industry's share in the total market will fall from the current 44.4% to 32.4%. The most striking increase will come from the nuclear fuel cycle market. The current market(1991-2000) encompasses ¥3.9 trillion (29% of the

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21 "Symposium on Plutonium Between Pro and Con Sides Takes One Step Toward Mutual Understanding," Atoms in Japan, September 1993, pp. 17-18.

22 "Nuclear Proponents and Opponents Debate Plutonium Use at Forum in Osaka," Atoms in Japan, November 1994, pp. 10-11.

23 "Reflecting Public Opinion on Nuclear Power for Long-Term Program: AEC's Public Hearing," Atoms in Japan, March 1994, pp. 4-5.

24 "Meiso Purutoniumu-Monju rinkai wo maeni (Whither Plutonium as Monju Nears Criticality?)," Series of articles, #3 (¥2 trillion-exorbitant reprocessing plant construction), Asahi Shimbun, January 9, 1994.

25 Japan Atomic Industrial Forum, "Chokitekina Jinzai Kakuho Eno Genshiryoku-kai no Kadai (Issues for nuclear industry to secure long-term human resources)," A report by Human Resource Issue Committee, March 1992.

total market), but is expected to grow to ¥14.2 trillion, the largest segment (about 40%) of the entire market during the 2020s.[26]

In addition to direct industrial interests, the Rokkasho project at its planned size is seen by some to serve a general Japanese interest in maintaining a strategic nuclear industrial base to meet possible future need or markets. For example, the JAIF report estimated that the number of required engineers for the supplier industry will grow from 24,000 in 1989 to 44,000 by 2010. The report says that "considering the lead times of developing necessary manpower resources, human resource issue is already a current problem."[27] Similar comment has been made by nuclear supplier companies regarding future manpower needs for FBRs.[28] Maintaining an industrial base for the uncertain future is a common argument in many countries used to support a particular industry. American legislators, for example, have defended continuing production of some large weapons systems using the same argument, notwithstanding the mitigation of the Soviet/Russian threat.[29] The American case has centered on the need to preserve the existing military industrial base against unanticipated future contingencies. The case for retention of the Rokkasho facility, despite the changes in context, has much in common, but the parallel is not well understood abroad.

D. Cultural and Technical Values

Every nation necessarily is affected in its planning by its traditions, historical experience, and cultural attitudes. Japan is no exception. Many elements stemming from those roots enter into the planning for the exploitation of nuclear power, such as the importance of energy security discussed earlier. Another conditioning element is a cultural view that it is wrong to waste resources. Accordingly, there is a strong appeal to the argument that the maximum value should be realized from all resources, in this case uranium. Hence, closing the fuel cycle as a way of extracting all of the usable energy from the uranium atom has been a significant goal in nuclear power planning.

Although this view is not explicitly written in policy documents, representatives from government and industry often state such views.

* ".. If we take the course the U.S. has adopted and tried to force upon other countries, and treat spent fuels as high-level wastes, ...we will end up with utilizing as little as 0.5 percent of the natural energy resource. This is not only a frivolous waste of resources, but costs society doubly because we are converting precious resources straight to waste."--Mr. Y. Akimoto, President of Mitsubishi Materials Corp., April 1994.[30]

* "It would be irresponsible for this generation to be the ones who by themselves used up all the world's resources and enjoyed an advanced consumption-oriented civilization,"-- Mr. Y. Moriguchi, Director

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[26]The numbers originally reported in the report separate the construction market for FBR reprocessing and final waste disposal site as "other construction," which is estimated to be ¥4.3 trillion (~12.0% of total market).

[27]JAIF, 1992, op. cit., p. 49.

[28]For example, Mr. T. Uebayashi of Mitsubishi Heavy Industry (MHI) is quoted with regard to FBRs, "In order to respond immediately to requests from the government and electric power industry we have to maintain about 100 people who are experts in the use of sodium". "Meiso Purutoniumu", Asahi Shimbun, op. cit., series #5 (A philosophy - Plutonium Promotion Policies Lack Persuasiveness at Home and Abroad), January 13, 1994.

[29]The Congress, for example, has been trying to maintain nuclear shipyards by ordering the production of Seawolf submarines. See E. Schmitt, "Deal by Senators Rescues Submarine Industry in Groton," The New York Times, June 30, 1995. For the generic argument on maintaining shipbuilding industry for national security reasons, see C.H. Whitehurst, Jr., "The U.S. Shipbuilding Industry: Past, Present and Future," Naval Institute Press, 1986.

[30]Akimoto, Y., "Plutonium and Civilization," prepared for the 27 the Annual JAIF Meeting, Hiroshima, April 14, 1994, p. 17.

of Nuclear Fuel Division, STA, January 1994.[31]

* "The plutonium issue is not the question of which energy source should be used in the foreseeable future, rather it is the question of 'philosophy'," -- Mr. T. Sakata, Director of Nuclear Fuel Division, STA, March 1993.[32]

Thus, there is strong cultural pressure to obtain the maximum value from all resources. As a result, closing the fuel cycle as a way of extracting all of the usable energy from the uranium atom has been a powerful driving force in nuclear power planning.

These national cultural values are reinforced by the engineering culture. Arguments for programs to extract the last joule from every milligram of uranium were common within the world's nuclear engineering community. In a very real sense, a genuine commitment to maximizing physical efficiency and minimizing waste is a matter of deep engineering conviction throughout the world and not just in Japan. For example, the American nuclear physicist Bernard Cohen wrote:

> ...it is my personal viewpoint that it is immoral to use nuclear power without reprocessing spent fuel. If we were simply to irretrievably bury it, we would consume all the rich uranium ores within about 50 years. This would deny future citizens the opportunity of setting up a breeder cycle...[33]

Although this engineering culture clearly plays a significant role within one segment of the Japanese nuclear community and is held in similar communities abroad, the extent and depth of these values are not widely appreciated outside of Japan. In fact, foreign observers express incredulity at the notion that many members of the Japanese engineering community hold an intense moral belief in the virtues of reprocessing and breeder programs.

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[31]Moriguchi, Y., "Japan's Perspective on Peaceful Use of Plutonium," Genshiryoku Kogyo (Nuclear Engineering), January 1994, translated in Science & Technology, Japan, JPRS-JST-94-029, 15 September 1994, p. 1.

[32]Quoted in Takagi, J., "Purutoniumu no mirai - 2041 nen kara no messeiji (Future of Plutonium - a message from the year 2041)", Iwanami Shinsho #365, December 1994, p. 65.

[33]Cohen, B., "The Nuclear Energy Option: An Alternative for the 90s," Plenum Press, New York, 1990, pp. 228-229.

V. FUTURE INTERNATIONAL IMPLICATIONS

Continuation along the current policy path will be likely to have several significant implications for Japan.

1. The unchanged commitment to the plutonium program, in particular to its commercial-scale development, will draw continuing international attention and concern. The present international concern about the Japanese commitment to plutonium reprocessing will continue and may well become more pressing as issues of nuclear safety and proliferation become more controversial on the international agenda. Japan's plutonium commitment, without convincing rationales, will be seen as providing the umbrella for other nations to move toward plutonium reprocessing and breeder reactors, with or without the encouragement of the Japanese Government. Although Japan's recent efforts to increase the transparency of its program will help to reduce international concern, those efforts will not eliminate the nature of the fundamental concern.

2. The credibility of Japan's overall nuclear program may be put in jeopardy since the rationale of the entire program has been linked to the successful commercialization of plutonium extraction and use. The more open discussion of nuclear programs inside Japan and the increasing international attention to plutonium recycling have led to increased questioning in Japan of the official rationale for the reprocessing program. Since the entire nuclear program has been tightly linked to the reprocessing of spent fuel and recycling of plutonium, any challenge to that rationale could lead to doubts about the overall nuclear power program itself.

The critical issue here is the basic link that has been drawn between the programs to reprocess and recycle plutonium and the overall nuclear program. The argument of the "inevitability" of plutonium use and reprocessing described in Chapter III can lead to a fixed view that the nuclear power program cannot exist without it. If any part of the argument then proved to be false, the credibility of the entire nuclear program could be endangered, even though plutonium use is not in fact necessary for the viability of nuclear power.

3. Serious events or policy changes outside Japan over which Japan will have no influence could have a major impact on the Japanese program. The "paradoxes of plutonium use" described in Chapter III have an important policy implication for the entire Japanese nuclear power program. The contribution of plutonium to energy security is based on the assumption that a plutonium economy within Japan, if developed with indigenous technologies, can be shielded from international political developments or resource shortages. That is a weak assumption. In fact, the Japanese nuclear programs could become more susceptible to international politics as its dependence on plutonium increases, since plutonium is and will remain one of the most sensitive materials in international affairs. Any serious proliferation event, terrorist incident, or accident involving plutonium could adversely affect plutonium programs in any country, and possibly basic nuclear power programs if they are closely linked. It is not realistic to believe that a plutonium economy can provide a shield from international influence.

One short-term possibility is a change in the IAEA safeguards definition of the significant quantity (SQ) of plutonium required to make a weapon. If the SQ is reduced from the current 8 kg to 4 kg, for example, it would become harder for the Rokkasho plant to demonstrate its 'safeguardability'. It might require another R&D program or significant design change, either of which could further increase the cost of the plant.

4. International concern about proliferation could become focused on Japan, as a by-product of dealing in other contexts with weapons-grade plutonium issues, and as other nations use Japan's program as a rationale for their own plans to extract and store plutonium, or to mount weapons development programs. One of the most important issues for non-proliferation policy is the management of weapons-grade plutonium recovered from dismantled nuclear warheads. As discussed in Chapter II, this will naturally also involve reactor-grade plutonium issues, and particularly the problem of civilian plutonium stockpiles. Japan's plutonium programs in that context cannot prevent becoming embroiled in what could be quite contentious international discussions and controversies.

In addition, it is inevitable that some international observers will perceive Japan as playing a leading role (implicitly or explicitly) in expanding worldwide plutonium use if other countries such as South Korea, China or other nations embrace plutonium reprocessing and recycling. International concerns about proliferation will thus likely lead to special and unwanted attention to Japan's programs and activities.

VI. SUGGESTIONS FOR MITIGATING INTERNATIONAL CONCERNS

In the light of this analysis, the authors offer suggestions that may be useful in the next nuclear power planning cycle in Japan.

1. Diversifying aspects of the fuel cycle program

The rationales offered for Japan's plutonium program, particularly those concerned with energy security and waste management, would have greater credibility if possibilities other than recycling were being more actively pursued (e.g. increasing support for uranium ventures, buying shares of new uranium mines, developing facilities for indigenous spent fuel storage and investing heavily in alternative energy technologies).

For example, even countries with advanced reprocessing programs such as France, Germany and the U.K. have conducted comprehensive reviews of alternative waste management options. This assessment of alternatives is an important piece that is missing in Japanese programs. The review would likely improve public confidence in the selection of technologies and policy options. It should be noted that reprocessing and the once-through option can be pursued in parallel, which can increase the flexibility of the entire nuclear power program.

2. Emphasizing long-term R&D

We recommend emphasizing a long-term R&D program aimed at more innovative technologies that may better serve the needs and priorities of global nuclear power programs, including better waste management, enhanced safety and lower costs. Appropriate models can be found in existing Japanese R&D programs as well as in other countries' programs. Possibilities include:

- Metallic or nitride fuel for higher performance and improved safety;
- Once-through high-burn up fuel which has high energy efficiency;
- Pyrochemical reprocessing or other innovative reprocessing steps which can reduce proliferation risks; and
- Small and modular type reactors with "inherent safety" and better economics.

Some research on reprocessing and breeders is clearly justified as a way of preserving a technological option if ever needed in the future. A long term, diversified R&D program would arouse relatively little international concern.

3. Avoiding premature commercialization of plutonium

We believe that other countries would be less concerned if Japanese commercial plutonium programs were stretched out, scaled down or suspended. Significant alteration along those lines in the Rokkasho reprocessing project would result in slower and smaller MOX recycling programs in LWRs. This would also shift Japanese reprocessing policy from a supply driven basis, where demand is artificially created in order to consume plutonium supplied by reprocessing, to a demand driven basis, where reprocessing takes place only when a need exists. As for overseas reprocessing, it may be worthwhile to negotiate with European reprocessors to either stretch out or link the operation with the timing of MOX contracts. Such changes would also reduce the costs borne by Japanese utilities. Our analysis suggests that the Rokassho plant would significantly raise the cost of nuclear power generation. Substitution of other activities would be necessary to mitigate local reaction to a reduction in Rokkasho plans.

4. Further opening of the policy process

Notwithstanding the recent positive changes made to make the policy process more transparent, greater availability of information and more opportunities for public debate about nuclear policies are necessary both to improve public knowledge of policy alternatives and to reassure foreign critics who believe there has been inadequate discussion of the choices Japan has made. Recent initiatives to establish and maintain an open dialogue between the Government and nuclear program opponents are encouraging. However, in addition to opening the process, it would be wise to expand further the practice of seeking outside, independent analysis. That can over time make for a policy process whose decisions have a better recognized basis of legitimacy and are more readily accepted internationally.

5. Enhancing confidence-building measures

Prominent efforts to open Japanese programs to foreign participation, inspection, and internationalization, some of which are currently underway, would serve the useful goal of deflating any concerns about ultimate Japanese intentions in its nuclear programs. Rhetoric alone is not enough, especially in the light of apprehension regarding motivations of the program. Some of the current initiatives, such as involving scientists of other countries in cooperative nuclear R&D, moving seriously to explore possible international mechanisms for control of plutonium stocks, and other such steps can help to improve international confidence in the Japanese program. It is likely that the greatest expansion of nuclear power programs will occur in Asia in coming decades. A report recently published by the nuclear subcommittee of the MITI Advisory Committee for Energy recommended a more active Japanese role in regional nuclear cooperation in Asia, including: (i) increased dialogue on nuclear safety, operation, and spent fuel/waste management, and (ii) tighter export controls consistent with international rules.[1] Such proposals help to demonstrate that Japan is willing and well positioned to help other nations, and to create a framework that will promote safe peaceful use and discourage proliferation.

6. Providing vigorous support for non-proliferation

The recent indefinite extension of the NPT, with the vigorous support of Japan and the United States, sets up the next stage of international non-proliferation policy. It is important that Japan be in the vanguard of support for implementation of the NPT and for non-proliferation in general, even if that means opposition to plutonium programs in other countries that could raise questions about Japan's own program.[2] The recent Japanese decision to penalize China for its decision to conduct nuclear weapon tests by reducing foreign aid is an encouraging sign of Japan's tough stance on non-proliferation. Willingness to be a model for plutonium monitoring and inspection, to provide financial support for the IAEA, and to participate in the efforts to reduce the risk of newly surplus weapons-grade plutonium are among the measures that can help to deflect criticism of the Japanese program.[3] For example, by accepting excess weapons plutonium for peaceful use, Japan could further delay or scale down its own reprocessing program. Plutonium shipments for such a purpose would likely face much less international criticism and could conceivably attract support.

7. Not encouraging commercial plutonium in other countries

Whatever arguments Japan has for proceeding with the creation of a "plutonium economy" within Japan, many responsible observers believe it would be very dangerous if the world at large accepted as standard the use of plutonium in nuclear power programs. It is tempting for Japan to encourage reprocessing and breeder reactors in other countries as a way to dilute the criticism of Japan's program, and along the way develop a commercial market for Japanese technology. In our view, such actions would greatly increase foreign criticism of the Japanese program.

The above suggestions, we believe, would not only reduce international concern over Japan's plutonium programs but also benefit the global non-proliferation regime in general, by supporting more flexible and diversified nuclear programs, developing less costly and more innovative nuclear technologies, increasing confidence in Japan's intention to use plutonium for peaceful purposes, and assisting in the critical issue of the management of surplus weapons-usable materials.

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[1]"Advisory Committee for Energy Publishes Interim Report Promoting Cooperation with Asia, Emphasizing Safety," Atoms in Japan, June 1995, pp. 4-6.

[2]Japan's commitment to plutonium makes it politically more difficult for the Japanese Government to support, for example, the lowering of the SQ of plutonium from 8kg (see discussion Chapter II) and to press on the issue of reduction of world plutonium surpluses.

[3]To manage newly surplus weapons grade stocks, the recent National Academy of Sciences report endorses MOX burning in existing LWRs or CANDUs and vitrification-with-waste options. The report suggests that MOX fabrication in Europe and Japan could contribute to safe management of weapons-grade stocks. See National Academy of Sciences, Committee on International Security and Arms Control, "Management and Disposition of Excess Plutonium: Reactor-Related Options," 1995, p. 8.

APPENDIX: LIST OF ORGANIZATIONS CONSULTED

Asahi Shimbun
British Nuclear Fuel Limited
CEA
Citizens' Nuclear Information Center, Japan
COGEMA, France
Department of Defense, UK
Department of Environment, UK
Department of Trade and Industry, UK
DGEMP
Federation of Electric Power Companies, Japan
Greenpeace International
House of Representatives, Japan
Institute of Energy Economics
Institute of Physique Nucleaire
Japan Atomic Industrial Forum, Inc.
Japan Development Bank
Japan Nuclear Fuel Limited
Ministry of Foreign Affairs, Japan
Ministry of International Trade and Industry, Japan
Mitsubishi Material Corporation
Nihon Keizai Shimbun, Inc.
Nuclear Electric, UK
Nuclear Energy Agency, OECD
Nucleonics Week
Rokkasho Village
Science Advisor to Cabinet Office, UK
Science and Technology Agency, Japan
University of Sussex
Tokai University
U.S. Department of Energy
U.S. Department of State
U.S. Office of Science and Technology Policy, The White House
University of Tokyo
WISE